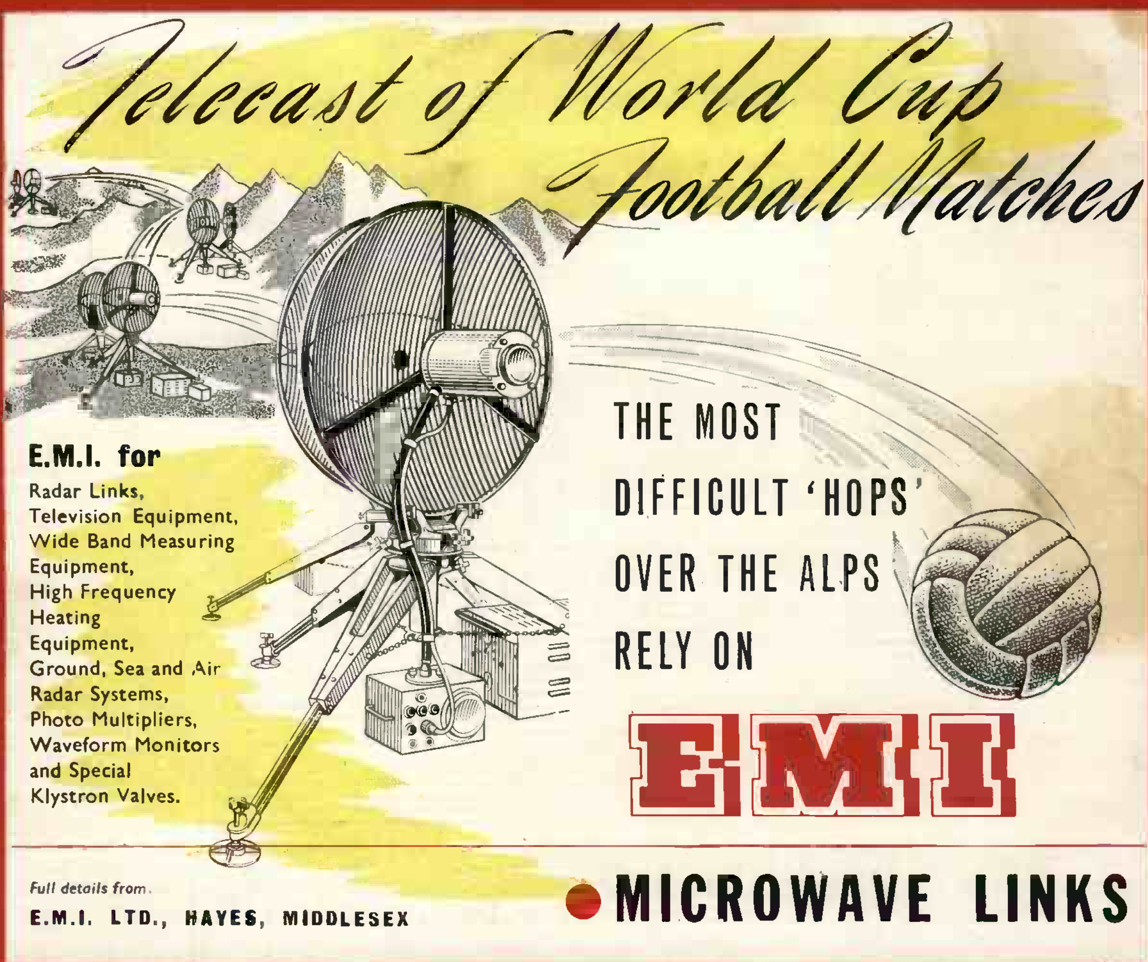
H.F. COMMUNICATIONS ISSUE

Electronic Engineering

JUNE 1954



TWO SHILLINGS

CLASSIFIED ANNOUNCEMENTS

OFFICIAL APPOINTMENTS

ADMIRALTY—ROYAL NAVAL SCIENTIFIC SERVICE. Experimental Officers and Assistant Experimental Officers required in Experimental Establishments in London, Portsmouth, Weymouth areas, Gloucestershire and Scotland. The majority of posts are for Engineers and Physicists (particularly with Electronics). Candidates must be British subjects. Qualifications: minimum H.S.C. (Pass Degree, H.N.C. or near equivalent an advantage). London salary (men) E.O. £720-£890, A.E.O. (according to age) £290-£645. All appointments are unestablished, but with some opportunities to compete for established posts. Application forms from M.L.N.S. Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A247/52. W 2130

AIR MINISTRY requires Scientific Officer (male) at R.A.F. station near High Wycombe, Bucks, for operational research duties, and theoretical studies in the field of communications and general electronics. Qualifications: First or Second Class Honours Degree in Physics or electrical engineering. Salary: Within range £445-£815. Post unestablished with possibilities of establishment through the Civil Service Commission for successful candidate while remaining under age 31. Opportunities for promotion to higher grade posts on staff of Scientific Adviser to Air Ministry. Application forms, quoting A109/54A from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1. W 2109

AIR MINISTRY requires Experimental Class Officers at establishment near Marlow, Bucks. Duties concern installation design of static and mobile radar and radio systems used by R.A.F. Work of engineering rather than laboratory type covering wide range of application of electronic engineering to meet operational needs of R.A.F. with which very close contact is maintained. Accepted candidates are eligible for nomination for membership of Officers' Mess, offering recreational facilities in congenial surroundings. Qualifications— at least Higher School Cert. (Science) or equivalent although higher qualifications in Physics or Electrical Engineering may be an advantage. Salaries within ranges. Experimental Officer (min. age 26) £690-£850 (male), or Assistant Experimental Officer £276 (at age 18) to £615 (male). Appointments unestablished. Application forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting D290/54A. W 2157

ASSISTANT (SCIENTIFIC). The Civil Service Commissioners invite applications for pensionable posts. Applications may be accepted up to 31st December, 1954, but early application is advised as an earlier closing date may be announced either for the competition as a whole or in one or more subjects. The Interview Board will sit at frequent intervals. Age at least 17½ and under 26 years of age on 1st January, 1954, with extension for regular service in H.M. Forces, but candidates over 26 with specialized experience may be admitted. Candidates must produce evidence of having reached a prescribed standard of education, particularly in a science subject and of thorough experience in the duties of the class gained by service in a Government Department or other civilian scientific establishment or in technical branches of the Forces, covering a minimum of two years in one of the following groups of scientific subjects:—(1) Engineering and physical sciences. (2) Chemistry, bio-chemistry and metallurgy. (3) Biological Sciences. (4) General (including geology, meteorology, general work ranging over two or more groups (1) to (3) and highly skilled work in laboratory crafts such as glass-blowing). Salary according to age up to 25: £250 at 18 to £380 (men) or £340 (women) at 25, to £520 (men) or £435 (women): somewhat less in provinces. Opportunities for promotion. Further particulars and application forms from Civil Service Commission, Scientific Branch, 30 Old Burlington Street, London, W.1, quoting No. S 59/54. W 2111

B.B.C. requires qualified Electrical Engineer for work on design, installation and electrical adjustment of aerial systems and associated transmission lines and filter circuits, etc., for medium, high and V.H.F. sound, television and F.M. transmitters. Applicants must be physically able and fit to climb and work on masts up to 750 ft. high and be prepared to travel extensively throughout U.K. Starting salary £645 p.a. rising by five annual increments to £880. Apply: E.E.O., B.B.C., London, W.1, quoting ref. E.899. W 2118

B.B.C. requires Senior Lecturer in General Section of Engineering Training Department, Evesham. Candidates should possess Degree or equivalent in Electrical engineering or physics. Previous experience in teaching and industry an advantage. Duties concern presentation of fundamental principles of sound and vision broadcasting to technical and non-technial staff and successful candidate will supervize four lecturers and generally develop work of Section. Starting salary £990 (maybe higher for exceptional qualifications) rising by five annual increments to £1,320 maximum. Apply E.E.O., B.B.C., London, W.1, quoting ref. E.914, within seven days W 2119

THE ATOMIC WEAPONS RESEARCH ESTABLISHMENT, Fort Halstead, Kent, has a vacancy for an Engineer (basic grade) to develop radar type equipment and units involving high voltage high speed transients, to meet production and service requirements and to issue drawings and give information to Contractors with subsequent advice during the early stages of production. Applicants should have served a recognised engineering apprenticeship and be Members of either the Institution of Mechanical or Electrical Engineers, or have exempting qualifications: previous experience in this type of work is essential. The salary range is £620 (age 25) to £960 per annum. Application forms from Administrative Officer (Recruitment), A.W.R.E., Aldermaston, Berkshire, quote ref. 16/W.G.E./42. W 2152

COVENTRY TECHNICAL COLLEGE. Required September 1954. Full-time Assistant Grade B, Electrical Engineering and Physics Department. Candidates should be Graduates or hold good technical qualifications and should have had industrial, service or research experience in electronics or telecommunications engineering. Salary, Burnham Technical Scale (£490-£755). Application forms and further particulars from Director of Education, Council House, Coventry. W 2121

ELECTRONICS TECHNICIAN required for work on 15 million Volt Linear Accelerator. Experience in pulse technique desirable. Salary according to experience in scale £450 to £550, plus London Weighting. Write enclosing two copies of references within seven days. Clerk to the Governors, St. Bartholomew's Hospital. London, E.C.1., marking envelope "Electronics." W 2107

MINISTRY OF SUPPLY, Radar Research Establishment, Malvern, Worcs. requires Electrical Engineers and Physicists for research and development work on radio and electronic equipment. Work ranges from fundamental research on circuitry and physics of solids, to devising and developing in collaboration with Industry, electronic devices for the Army, R.A.F. and Naval aviation. Ample scope for initiative and originality over very wide field concerned mainly with electronics. Minimum qualifications Higher School Certificate (science) or equivalent, but further training in physics or electronic engineering to H.N.C. or Degree standard may be an advantage. Salaries within ranges, Experimental Officer (minimum age 26), £690-£850, or Assistant Experimental Officer £276 (age 18)-£615. Women somewhat less. Appointments unestablished. Application forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A 121/54A. W 2143

MINISTRY OF SUPPLY requires Physicist or Engineer at Instrument and Photographic Department of Royal Aircraft Establishment, Farnborough, to work on development of new automatic pilots and adaptation of existing equipment for special purposes. This will involve design of electro-mechanical instrument devices, supervision of associated experimental work and considerable contact with industry. Minimum qualification—1st or 2nd Class Honours Degree or equivalent in physics or engineering, Working knowledge of electronics and servo-techniques desirable. Candidates must be keen on practical as well as theoretical work, medically fit and willing to fly as observer. Salary within range, Scientific Officer, £445-£815. Women somewhat less. Appointment unestablished. F.S.S.U. benefits may be available. Application forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting D. 272/54-A. Closing date 11th June, 1954. W 2133

MINISTRY OF SUPPLY requires Experimental Officers in Radio Division of Royal Aircraft Establishment, Farnborough, Hants. Work concerned chiefly with the development of electronic equipment, radio frequency measurements at centimetric wavelengths and for other detailed technical investigations. Qualifications: Higher School Cert. (Science) or equivalent but further training in Physics or Electrical Engineering to Degree standard, H.N.C. or Final City and Guilds Certificate in Telecommunications may be an advantage. Appointments graded according to age, experience, etc., within ranges. Experimental Officer (minimum age 26) £690-£850 or Assistant Experimental Officer £276 (age 18) £615. Women somewhat less. Appointments unestablished, application forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting D. 289/54-A. Closing date 12th June, 1954. W 2154

POST OFFICE: EXPERIMENTAL OFFICER The Civil Service Commissioners invite applications from men for this pensionable post in the Research Station at Dollis Hill, London. The work is in the electronics field and the duties involve investigations on both guided and unguided transmissions in V.H.F. and U.H.F. ranges. Candidates must have been born on or before 31st December, 1923. They must normally have a Pass Degree (or equivalent) in an appropriate subject or a technical qualification, e.g. H.N.C. in appropriate subjects or with appropriate endorsements. Experience in the field of electronics is essential. A candidate without the academic qualifications but who has had exceptional experience may be admitted. Salary £720 to £890. Exceptionally starting salary above the minimum in an appropriate case. Further particulars and application forms from Civil Service Commission, Scientific Branch, 30 Old Burlington Street, London, W.1, quoting No. S4330/54. Completed application forms must be returned by 10th June, 1954. Candidates born between 1st January, 1924 and 31st December, 1928, may be considered but must apply through the open competition (No. S94-95/54). W 2148

THE WAR OFFICE requires for No. 35 base workshop, R.E.M.E., Old Dalby, Leicestershire: One Mechanical Engineering Officer (main grade) to control workshop repairing radar and associated equipment. Knowledge and experience of modern electronic and allied engineering progress and process methods and technique of management essential, also ability to organize large repair programmes and production. Inclusive salary range £1,000-£1,320 (London). Applicants must be British of British parentage and Corporate Members of the Institution of Electrical Engineers or have passed or be exempt from Sections A and B of their membership examination. Starting salary fixed according to age, qualification and experience on range quoted. Annual increments subject to satisfactory service. Post temporary but long-term possibilities. Application forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting D. 258/54. W 2129

TRINITY HOUSE, London. Applications are invited for appointment to the following posts in the Electrical and Electronics Department of the Corporation of Trinity House, London. (a) One Engineer required for work in connexion with the development of electrical and electronic navigational aids. This includes the development of optical systems for fog detection apparatus, development of fog signals, audio monitoring equipment and automatic control and indication equipment. Salary Scale: £1,030 rising to £1,230 per annum. (b) Two Experimental Officers required for work as set out in (a). Salary Scale: £720 rising to £890 per annum. (c) Two Engineering Assistants required for planning and progressing electrical installations, including engine-generating plant up to

40KVA wiring and distribution and the design of small component parts. Salary Scale: £623 rising to £734 per annum. (d) Two Laboratory Assistants required for general laboratory work in connexion with (c) above and radio/radar equipment. Salary Scale: £290 (age 18) rising to £645 per annum. (Highest age pay): £520 at age 26). (e) Four Radio Maintenance Assistants required to maintain radio and radar equipment in shore stations and ships. Salary Scale: £407 rising to £550 per annum. Minimum linked to age 25 years. Minimum qualifications required: For (a) and (b) Science Degree, Corporate Membership of the Institute of Electrical Engineers or equivalent. For (c) Higher National Certificate in Electrical Engineering. For (d) Higher School Certificate (Science) or equivalent. For (e) a knowledge of the fundamental principles of radio and radar and practical experience in maintenance of use of such equipment. All candidates must be medically fit and of British nationality. Appointments. A proportion of those appointed may be placed on the permanent established staff after a satisfactory probationary period. Applications should be made in writing to the Secretary, Trinity House, London, E.C.3, not later than 18th June, 1954, stating age, occupation, qualifications and experience and enclosing copies of recent testimonials. W 2156

UNIVERSITY COLLEGE OF NORTH WALES, BANGOR. Applications are invited for the Chair of Applied Electricity, which has been instituted within the department of Physics. Candidates should have experience of Applied Electronics or Light Current Electrical Engineering. The appointment will date from October 1, 1954, and the initial salary will be £1,700 p.a., with superannuation and family allowances. Fifteen copies of the application should reach the undersigned, from whom further particulars may be obtained, not later than May 24, 1954. Kenneth Lawrence, Secretary and Registrar. W 2090

UNIVERSITY OF SOUTHAMPTON. A Technician with an interest in the development of Electrical instruments is required in the Department of Mechanical Engineering. The selected candidate will be expected to apply his knowledge to the problems of measurement which occur in general engineering research. Technical education to Higher National Certificate or equivalent standard is required. Applications in writing giving full details of education, qualification and experience together with the names of two persons to whom reference may be made, to the Secretary and Registrar, The University, Southampton, before June 15th. W 2126

WAR OFFICE require Assistant Mechanical Engineering Officer (Recruitment Grade Professional) at Donnington, Salop, to organize, control and supervise a workshop sector employing 30 to 40 civilians engaged on repair and calibration of electrical and electronic test equipment. Inclusive salary range £645 to £960 (Provincial). Applicants must be British of British parentage and be Corporate Members of the Institution of Electrical Engineers or have passed or be exempt from Sections A and B of their membership examination, or possess a University Engineering Degree. Starting salary fixed according to age, qualifications and experience. Annual increments subject to satisfactory service. Posts temporary but long-term possibilities. Application forms quoting reference D423/53A from M.L.N.S., Technical and Scientific Register (K), Almack House, 26 King Street, London, S.W.1. W 2153

WAR OFFICE require three Technical Assistants Grade II (unestablished) for Electronics Wing, R.E.M.E. Establishment, Malvern, Worcestershire. Duties are to collect and collate data for use in preparation of reports on newly developed Electronic Equipments and to write technical handbooks, covering maintenance and repair of Army Electronic Equipments. Applicants must be British of British parentage, possess an Ordinary National Certificate (or its equivalent) and have served suitable apprenticeship and have sound electronic knowledge. Experience of writing reports is desirable but not essential. Salary in range £592-£702 per annum (at age 30) less £20 p.a. for every year under 30. Starting according to age, qualifications and experience. Annual increases subject to satisfactory service. Write giving date of birth, education, full details of qualifications and experience of posts held (including dates) to Appointments Officer, Ministry of Labour and National Service, 1-6 Tavistock Square, W.C.1, quoting E.C.214. No original testimonials should be sent. Only candidates selected for interview will be advised. W 2150

SITUATIONS VACANT

The engagement of persons answering these advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18-64 inclusive or a woman aged 18-59 inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order, 1952.

AERONAUTICAL RADIO ENGINEERS. Marconi's Wireless Telegraph Co., Ltd., are continually expanding their already wide activities in the field of aeronautical radio. There are posts available for development, project, field and sales engineers on all aspects of airborne and ground communications and radio and radar navigational aids for both civil and military purposes. Any engineer who is interested in this field should apply in confidence, giving details of his experience, etc., and quoting reference S.A.44, to The Manager, Aeronautical Division, Marconi's Wireless Telegraph Co., Ltd., Dept. C.P.S., 336/7 Strand, W.C.2. W 2053

A LARGE and well-established engineering company situated in the East London area require tool designers and draughtsmen. Applicants should have had tool room apprenticeship or equivalent followed by experience on first-class tool work, in the light mechanical and electrical fields. Applications are invited from men of sufficient experience and ability to justify very good salaries. Excellent working conditions and staff pension scheme in operation. Please write, in confidence, giving details of experience to Box No. W 2114.

AN ELECTRONIC ENGINEER, age 25 to 35, is required to fill an interesting appointment in the Development Laboratory of the General Electric Company, Ltd., at Stanmore. Work involved will include development of airborne radar equipment and a knowledge of aircraft electrical installation would be useful. Possession of a University Degree is desirable, and a working knowledge of elementary Physics would be advantageous. Applications should be made in writing to the Staff Manager (Ref. EE/AMMV), Brown's Lane Division, The G.E.C. Stanmore Laboratories, The Grove, Stanmore Common, Stanmore, Middlesex. W 2100

AN ELECTRONIC ENGINEER, possessing an Academic or Industrial Degree and having at least five years' practical experience is required for development work on a wide range of electronic instrumentation. The position offers ample scope for advancement in a rapidly expanding department. Applicants should be 25 to 35 years of age, and should write giving full details to Box No. W 1030.

AN OUTSTANDING OPPORTUNITY is offered to an Electronics Liaison Engineer in the New Electronic Equipment Division of an old established electrical company who are expanding to a South Coast area. The qualifications for this post are a sound technical background, considerable knowledge and experience of centimetric radar systems, pulse and microwave techniques. Applicants should also be capable of co-ordinating the work of design and production authorities, and be able to accept the responsibility for assessing test equipment and specification requirements for Radar production projects. The salary for this post will be commensurate with ability. Interested applicants should write giving full details of the above experiences and age to Box No. W 2093.

APPLICATIONS ARE INVITED from Engineers and Draughtsmen as shown hereunder: (a) Design Engineers and Draughtsmen with experience of design of television, Services communication equipment and/or aircraft accessories. (b) Tool design draughtsmen with experience of small to medium class press tools, jigs and fixtures. The vacancies, which call for men of sound technical ability, offer good progressive positions. A good salary will be paid to the selected applicants and will be commensurate with previous experience. Applications should be addressed, in the first instance for the attention of the Personnel Manager, The Plessey Company Limited, Vicarage Lane, Ilford, Essex. W 2117

APPLICATIONS ARE INVITED from suitably qualified Engineers for Senior Positions in the Television and Domestic Broadcast Receiver Development Laboratories. The vacancies offer considerable scope in the application of Transistor and Printed Circuitry to this field. Applications stating fully, age and experience and salary required should be sent to The Personnel Manager, Box No. W 2134.

ARMSTRONG SIDDELEY MOTORS LIMITED. As a result of the creation of a separate Rocket Division of Armstrong Siddeley Motors, opportunities exist in a new and interesting field of engineering. Applicants should have an appropriate Degree or Higher National Certificate. Previous experience in this work is not essential if the applicant has enthusiasm and ability. Vacancies exist in all grades of the following positions: Technical Assistants, Electronic Engineers, Chemists, Stressmen, Designers, Draughtsmen. Apply to: Personnel Manager (Reference SAI-Rockets), Armstrong Siddeley Motors Ltd., Parkside, Coventry. W 2104

A SENIOR APPOINTMENT will shortly be filled in the London laboratory of a firm holding contracts in guided weapon and kindred fields. Engineers who wish to be considered for this vacancy should be graduates and should have had some experience in industrial engineering laboratories. Some production engineering experience in addition to microwave electronic and/or servo experience would be an advantage. Starting salary will range according to age and experience and will be on a generous scale and will be subject to good increases, according to merit. Pension and life assurance schemes are in operation. Write giving full details in confidence to Box No. W 2146.

A VACANCY occurs with a leading manufacturer for a man experienced in Wave guide measurement. An ex-Serviceman with the necessary experience of Testing and Fault Finding on Radar Gear would be considered. Write, stating age, experience and salary required to Box No. W 2136.

BLACKBURN AND GENERAL AIRCRAFT LTD., have vacancies in the Electronics Section at Brough, for One Senior and Two Junior Technicians for work on strain-gauging, electronic instrumentation and vibration investigations on aircraft and gas turbines. Previous experience of this type of work essential for senior grade and desirable for junior grade. The Company's programme on Military and Civil aircraft offers excellent prospects of permanent and interesting work under congenial conditions at salaries commensurate with qualifications, ability and experience. Applications giving full particulars of age, training, etc., to:—The Personnel Manager, Blackburn & General Aircraft Ltd., Brough, Yorks. W 2001

BRITISH ACCOUSTIC FILMS have vacancies in their laboratories at Shepherds Bush for Engineers or Physicists to work on sound recording and reproducing equipment, including Stereophonic systems. Applicants should have good qualifications, preferably an Honours Degree, or give evidence of exceptional ability and interest in electronics and sound reproduction. Five-day week and Pension Scheme. Salary according to qualifications and experience. Applications should be made in writing to the Personnel Manager, British Accoustic Films Ltd., Woodger Road, W.12. W 1026

BRITISH TELECOMMUNICATIONS RESEARCH LTD., a Company associated with the Automatic Telephone & Electric Co., Ltd., and British Insulated Callender's Cables Ltd., has a vacancy for a senior engineer for work on the development of specialized test equipment for telecommunication systems. There is a superannuation scheme and the Company works a five-day week. Application should be made to the Director of Research, British Telecommunications Research Ltd., Taplow Court, Taplow, Bucks, giving age and full details of education, qualifications, experience and approximate salary required. W 2096

CHIEF OF TEST required by well established transformer manufacturers in North West London area. Interesting position involving experimental and development work. All types of transformers up to 20-kVA including audio frequency. Applicant must be used to working to a high degree of accuracy also A.I.D. and Inter-Services. Permanent progressive position, pension scheme and life assurance. Write stating age, experience, salary required. Box No. W 1016.

CLASSIFIED ANNOUNCEMENTS
continued on page 4

The engagement of persons answering these advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18-64 inclusive or a woman aged 18-59 inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order, 1952.

TELEVISION ENGINEERS required for Demonstration Installation Unit (T.V. Transmission Equipment). Must be willing to travel overseas. Apply by letter in first instance to: Engineer in Charge, Demonstration and Installation Section, Pye Ltd., Cambridge. W 2008

TEST ROOM SUPERVISOR required by Electronic and Radar firm of International repute, for appointment which will provide an outstanding opportunity to the successful applicant in an entirely new production group located in the South Coast area. Essential qualifications are:—(a) Good technical background. (b) Experience of the testing requirements associated with the production of microwave radar, servo and pulse equipment. (c) Ability to organize and control staff. Superannuation scheme exists and housing assistance may be given. Write fullest details of education, experience and age to Box No. W 2105.

THE BRITISH TABULATING MACHINE CO., LTD., require an "Electronic" Draughtsman for their Research Laboratory at Stevenage. Work consists mainly of drawing circuit diagrams, with some mechanical drawing for chassis and component layout. Previous experience desired. Applications, giving particulars as to age, previous experience and salary required should be addressed to Personnel Officer, at Letchworth, Herts. W 1024

THE ENGLISH ELECTRIC COMPANY LIMITED have vacancies at Luton and in Australia for Junior Engineers and Laboratory Assistants. Applicants should have a sound knowledge of electronic circuitry with preferably some radar experience. These positions are permanent and progressive and attractive salaries are offered for able and experienced men. Assistance with housing for some of the posts may be given, and a staff pension scheme is in operation. Application to Dept. C.P.S., 336/7 Strand, W.C.2., quoting reference 456V. W 2071

THE ENGLISH ELECTRIC VALVE CO., LTD., Chelmsford, are requiring Senior and Junior Graduate Engineers for work on magnetron and klystron development work. Please apply to Dept. C.P.S., 336/7, Strand, W.C.2, quoting Ref. 419M. W 2138

THE GENERAL ELECTRIC CO., LTD., have vacancies at Stanmore for Electronic and Electrical Engineers for work in Development Laboratories. There are a few senior positions available to experienced men with a University Degree or an equivalent qualification and more junior positions for men of O.N.C. standard and/or with previous experience in development work. The work is interesting and there are openings in each of the following fields:—1. Servo-mechanisms and Magnetic Amplifiers. 2. Microwave Circuits. 3. Pulse Circuits. 4. General Radar circuits and C.R.T. radar presentation. 5. Preparation of G.W. equipments for trials. 6. Stabilized Radar aerials. Applications should be made in writing stating age, qualifications and experience and should indicate the specific interest of the applicant. All positions are permanent in ideal working surroundings and there are excellent welfare and social facilities. Please reply to the Personnel Manager (Ref. EE/MW.2), Brown's Lane Division, The G.E.C. Stanmore Laboratories, The Grove, Stanmore Common, Stanmore, Middlesex. W 2099

THE GENERAL ELECTRIC CO. LTD., Brown's Lane, Coventry, require Senior and Junior Electronic Development Engineers for work on Guided Weapons and like projects, particularly in the field of Microwave and Pulse Applications. Mechanical Development Engineers, Designer Draughtsmen and Draughtsmen, preferably with experience of Radar type equipments, also required for the above projects. Salary according to age, qualifications and experience. Apply by letter stating age and experience to the Personnel Manager (Ref. R.G.). W 169

THE RESEARCH LABORATORIES of The General Electric Co., Ltd., East Lane, North Wembley, Middlesex, have a vacancy for an Electronic Engineer with General B.Sc. degree or Higher National Certificate to work on life investigation of radio valves. Candidates for this position must have completed National Service if under 26 years of age. Apply in writing to Staff Manager (Ref. RLO/23), giving full particulars of age, qualifications and experience. W 2076

TIME STUDY ENGINEER and Rate Fixer required by a well-established engineering company engaged in the manufacture of electronic and associated equipment. Applicants should have training in effort rating and in the practical application in time and motion study of small batch production or radar, electronic equipment and electro-mechanical instruments. The vacancies present attractive opportunities to keen and energetic men of good experience and qualifications. A generous salary will be paid to the selected applicant. Please reply, giving full details of experience to Box No. W 2115.

TRANSFORMER DESIGNER required for development projects involving audio-frequency power transformers, pulse transformers, oil-filled units, etc. Apply stating age, qualifications and experience to the Personnel Manager (Ref. R.G.), The General Electric Co., Ltd., Brown's Lane, Allesley, Coventry. W 192

TRANSISTORS. The British Tabulating Machine Co., Ltd., Icknield Way, Letchworth, Herts, has a vacancy for a graduate engineer or physicist for research and development work on the use of Transistors in pulse and switching circuits. Applicants should possess an Honours Degree in Physics or Electrical Engineering, and have experience of either Transistor circuit techniques or of pulse circuits as used in digital computing, radar, etc. Salary will be based on qualifications, age and experience. Applications stating age, experience and training should be sent to Personnel Officer. W 1995

URGENTLY REQUIRED. Young single men as Electronic Wiremen, also Junior and Senior Test Engineers in connexion with Television Cameras and ancillary equipment. Apply in writing to Personnel Officer, Dept., 24, Pye Ltd., Radio Works, Cambridge. W 2128

VACANCIES EXIST at all levels for Engineers in the Research Laboratories of S. Smith & Sons (England) Ltd. There are also a number of vacancies for exceptionally skilled laboratory, mechanics and wiremen. The laboratories are of modern design and are situated in pleasant Cotswold country near Cheltenham. Posts are permanent and a Staff Pension Scheme with life insurance is in operation. Married staff after a short period of satisfactory probationary service, may apply for a house on the company's modern housing estate. Promotion prospects are good in these continually expanding laboratories. Applicants for the more senior posts of Project Officer or Specialist Engineer which carry a salary of up to £1,500 per annum should preferably have an Honours Degree or equivalent qualification, and in the former case should have had experience of controlling a project team. General experience in some of the following fields is a necessary qualification for Project Officers, expert knowledge in one field is essential for a specialist. Applicants for less senior posts should have some experience in one or more of the fields listed. (a) Mathematical Study of Controlled Stability. (b) Aircraft Navigation. (c) Automatic pilots. (d) Electronics (preferably including knowledge of magnetic and transistor amplifier techniques). (e) Electric and/or Hydraulic Servomechanisms. (f) G.W. Field Trials. Travelling expenses will be paid to applicants selected for interview. Write in first instance for application form to: Personnel Manager, S. Smith & Sons (England) Ltd., Bishops Cleeve, Nr. Cheltenham, Glos, quoting Ref. GW7/F. W 2124

VACANCIES EXIST for Junior Engineers and Laboratory Assistants on work connected with expanding programme involving Radar and associated devices. Qualifications required are as follows.—Junior Engineers should be of Graduate standard with preferably some service or laboratory experience of radar. Laboratory Assistants should be of Matriculation standard in mathematics and physics and familiar with the use of normal test equipment. A student member would be suitable. Salaries according to age and experience. Applications should be made in writing in the first instance to the Chief Development Engineer, Decca Radar Limited, 9 Davis Road, Tolworth, Surbiton, Surrey. W 1991

VICKERS-ARMSTRONGS LTD., Crayford, Kent, have a number of vacancies in their Computer Laboratory as follows: 1. Honours Graduates to engage in research and development work on commercial electronic computing machines and devices. 2. Engineers and Technicians to engage in development and design of electronic commercial computing machines and devices. Qualifications University Degree, Higher National Certificate or equivalent. 3. Electrical Draughtsmen to engage in the design of electronic commercial computing machines and devices. Also required: Junior and Senior Electrical Draughtsmen accustomed to work concerned with circuit and cable lay-out particularly in connexion with Naval and Military equipment. Experience in the design of small electrical apparatus and lay-out of electronic equipment will be an advantage. Also required, Graduate Electrical Engineers, age about 30, with Degree or H.N.C. and practical experience in servos, electronics or tele-communications, for development work on low-power servo systems. Applications should be made in writing to the Manager, Engineering Department and Labour. W 2057

VICKERS-ARMSTRONGS LIMITED, Weybridge Works: Guided Weapons Development. Applications are invited from experienced Engineers for senior staff appointments in the following grades:—Electronic Engineer to lead Group on Servo Control and Simulator Design. Electro-Mechanical Designer—to develop small mechanisms. Vacancies also exist for: Engineers, Technical Assistants, Draughtsmen (Senior, Intermediate, Junior and Trainee), Laboratory Assistants and Mechanics. For work on structural, electronic, electrical and mechanical engineering development. Suitable academic qualifications are required; Engineers and Technical Assistants—graduate or equivalent Draughtsmen and Laboratory Assistants—H.N.C. standard. Applications should be made to: Employment Manager, Vickers-Armstrongs Limited, Weybridge Works, Weybridge, Surrey. W 2075

WANTED LABORATORY ASSISTANT, Ordinary National Certificate standard for Television and Radio Coil Factory. Forty-four hour, five-day week. Salary in accordance with experience. Apply to Miss K. S. Cowan, Personnel Officer, Mitcham Works Ltd., Winchelsea Road, Harlesden, N.W.10. W 194

WIREMAN for modern research laboratory, capable of working to verbal instruction and able to do original layouts. City and Guilds or National Certificate an advantage, at least three years' experience imperative. (Ref. 71). Write in detail, quoting reference No. of position sought to: The Personnel Dept. (Technical Employment), De Havilland Propellers Limited, Hatfield, Herts. W 2089

A further "Situations Vacant" advertisement appears in display style on page 111.

SITUATIONS WANTED

CHIEF OF DEPARTMENT specializing in Servo Systems, Analogue Computors, Aircraft Instruments, Magnetic Devices and Component Development desires change where abilities to establish leadership and to meet delivery dates are appreciated. Middle thirties. £2,000 p.a. Box No. W 1036.

EXPERIENCED Technical Author seeks publications position. Midlands. Box No. W 1042.

TECHNICAL WRITER available for limited period. Box No. W 1041.

FOR SALE

A.F. SIGNAL GENERATOR for Sale. Guaranteed in perfect condition, covers 20c/s to 50kc/s approx. 1 per cent, sine and square outputs, attentuator, etc., in strong cast complete with full instruction sheets. Bargain £9 only, must sell. Send s.a.e. for full details. Box No. W 1034.

CABLE/FLEX. much cheaper in odd length coils. Short lengths supplied. Lists BDC. 591 Green Lanes, London, N.8. W 1962

DECAL. Transfer Labels for marking electronic equipment. Standard edition approximately 750 titles covering all aspects of electronics, radio, recording, etc. 4s. 9d. plus 3d. post. Amateur Edition, devoted to amateur

CLASSIFIED ANNOUNCEMENTS
continued on page 12

FOR SALE (Cont'd.)

radio, recording, etc., approximately 300 titles. 3s. 6d. plus 6d. post. Both in black or white. Alexander Equipment Ltd., Sandhurst, Kent. Sandhurst 276. W 1031

GERMANIUM DIODES 1s. each. Large quantities cheaper. BDC, 591 Green Lanes, London, N.8. W 1040

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MAGSLIPS at 1/10th to 1/20th of List Prices. Huge stocks. Please state requirements. K. Logan, Grove Road, Hitchin 1744, Herts. W 183

METALWORK. All types cabinets, chassis, racks, etc., to your own specifications. Philpott's Metal Works Ltd. (G4BI), Chapman Street, Loughborough. W 2000

OIL FILLED CONDENSERS. Dubilier 0·5 × 0·5 MFD — 2,200 volts. Quantity at large discount. Box No. W 2125.

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STABILIZED POWER UNITS. Boldre series 100 watts, stabilized 150-500V, variable. Unstabilized 300-700 6·3V A.C. 100 watt. Impedance less than 1Ω, ripple 5 MV, stability 0·02 per cent. Suitable for all main service voltages and frequencies. A. Laboratory model: £79 10s. B. General purpose model: £57 10s. D Skeleton model for building into equipment: £42. Reduction for small ranges or spot volts. Power units designed and built to specification. Sub-contract wiring, assembly or potting. Inter-unit cabling made up exact lengths. Newtown Industries, Lymington, Hants. W 1027

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CITY & GUILDS (Electrical, etc.) on "No Pass—No Fee" terms. Over 95 per cent successes. For full details of modern courses in all branches of Electrical Technology send for our 144-page handbook—Free and post free. B.I.E.T. (Dept. 337C). 29 Wright's Lane, London, W.8. W 142

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WEBB'S SERVICE DEPT. for complete renovation of complex communication receivers of any make. Test report issued showing sensitivity selectivity, signal/noise equal to, or better than, makers' original figures. Webb's Radio, 14 Soho Street, London, W.1. W 196

PATENTS

EXPLOITATION OF PATENTS. The Proprietors of the following British Patents desire to secure commercial exploitation by licences in the United Kingdom:—British Patent No. 671537—Microwave Lens Lattice Matched to Space Impedance. British Patent No. 650041 — Improvements in or relating to Antennæ or Radiators for Electromagnetic Waves. British Patent No. 579746—Improvements in or relating to Directive Electro-Magnetic Antenna Structure. Please reply to Box AC 89517, Samson Clarks, 57/61 Mortimer Street, London, W.1. W 2103

AGENCIES

CANADA. Technical Director of medium-sized Electronic Company, travelling to Canada, wishes to contact Electronic and Electrical Manufacturers interested in an efficient sales and servicing organization for their products in that country. Box No. W 1033.

Now SERVOMEX

achieve an even higher standard of accuracy with the new . . .

AC2 10 amp. Voltage STABILISER

Servomex AC voltage stabilisers have rapidly become standard equipment, and have been widely adopted by leading government and commercial laboratories throughout the country. The new model, type A.C.2, embodies several improvements, check these features :—

- Continuous servo gives accuracy of 0.25%
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- Velocity feedback gives complete stability, independent of friction
- Unaffected by changes of amplitude, frequency, waveform, or power factor
- High output, 10 amps. at 200-240 volts
- Efficiency 95%
- Brush changing in a few seconds
- Normally supplied for rackmounting, external case (as illustrated) optional extra

Please write for new data sheet.

The Servomex range also includes low voltage, high current D.C. and A.C. Stabilisers, Magnetic Amplifiers, Motor Controllers, etc.

SERVOMEX CONTROLS LTD.

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for the measurement of

SURGE, FLUCTUATING OR STEADY PRESSURES

(Gauge or Differential)

FOR SURGE, FLUCTUATING OR STEADY PRESSURES

TYPE NO. 448 *(as illustrated)*
0 - 1000 p.s.i. to 0 - 50,000 p.s.i.

TYPE NO. 449
0 - 10 p.s.i. to 0 - 1,000 p.s.i.

Both the above types comprise a 4-arm strain gauge compensated bridge, producing a voltage output (m.V.) directly proportional to the applied pressure.

TYPE NO. 522 0 - 15 p.s.i. to 0 - 2,500 p.s.i.

Pressure is applied to a diaphragm which is caused to change the inductance of an iron cored circuit. This change of inductance can then be used either to create out-of-balance in a bridge or to frequency modulate an oscillator.

FOR STEADY OR SLOWLY FLUCTUATING PRESSURES

TYPE NO. 548
0 - 5 p.s.i. to 0 - 4,000 p.s.i.

Comprising a Bourdon tube or bellows operating a precision potentiometer. These transducers produce a voltage output directly proportional to pressure.

JLT GROUP

J. LANGHAM THOMPSON
LIMITED
BUSHEY HEATH · HERTS

Telephone: Bushey Heath 2411 · Grams and Cables: "Tommy Watford"

ALL-POWER

REGULATED POWER SUPPLIES

SERIES 500

4 NEW MODELS

RATED FOR 350mA OUTPUT

The four models detailed below are similar to the existing 500 series units and have the same overall physical dimensions.

AVAILABLE FOR PROMPT DELIVERY

Model 506
(fitted with end frames)

ABRIDGED DATA

(Further information on request)

	Data	Model 506	Model 507	Model 508	Model 509
Main+VE Stabilizer	Output	200-500V 350mA	200-500V 350mA	0-500V 350mA	0-500V 350mA
	Number of Ranges	2	2	4	4
	Voltage Stabilization	±0.02%	±0.002%	±0.1%	±0.002%
	Effective Output Resistance (max.)	0.2 Ω	0.02 Ω	0.5 Ω	0.02 Ω
	Output Ripple (rms. max.)	2mV	1mV	3mV	1mV
—VE Supply Stabilizer	Outputs	—	—	250V 25mA 0-250V 1mA	250V 25mA 0-250V 1mA
	Voltage Stabilization	—	—	±0.05%	±0.002%
	Output Resistance (max.)	—	—	1 Ω	0.01 Ω
	Output Ripple (rms. max.)	—	—	2mV	1mV
Unstabilized +VE H.T. Supply 350mA max.		470V 630V	470V 630V	320V 470V 630V	320V 470V 630V
Unstabilized A.C. Supply		6.3V 10A	6.3V 10A	6.3V 10A	6.3V 10A
Price		£77	£98	£88	£106

STANDARD UNITS. All models are supplied as standard for mounting in 19 in. racks and are fitted with fully protective covers.

EXTRAS. To convert from rack mounting to bench use the following extras are available :—

Polished hard-wood reinforced end frames ... ... £1 15 0 per pair

Steel instrument case of new design ... ... £4 10 0 each

PRICES. Prices are quoted net ex works and are subject to variation without notice.

ALL-POWER TRANSFORMERS LTD. . CHERTSEY ROAD, BYFLEET, SURREY

Tel. : BYFLEET 3224/5

COSSOR *presents...*

The new Cossor Double Beam Oscillograph

MODEL 1052

Two similar amplifier channels with an approximate gain of 2000 and an upper frequency response of 5 megacycles (minus 6 DB) are features of this new Cossor Double Beam general purpose oscillograph. The repetitive or triggered time base has a sweep duration from 200 milliseconds to 5 microseconds.

The instrument will operate from power supplies of any of the various frequencies and voltages encountered in the Armed Services or from standard civil supply mains. The top and side panels are quickly detachable to allow inspection and a removable plate at the rear of the instrument allows access to tube plates, anode and modulator.

and Voltage Calibrator

MODEL 1433

Primarily designed to be used with the new Cossor oscillograph the Cossor Voltage Calibrator model 1433 provides an accurate means of calibration of input voltages to the plates or amplifiers of any oscillograph. Calibrating voltages are read directly from a wide scale meter without any computation being necessary. Measurements can be made to an accuracy of $\pm$ 5% and the instrument can be used in any application where a source of accurately-known voltage is required.

COSSOR ELECTRONIC INSTRUMENTS

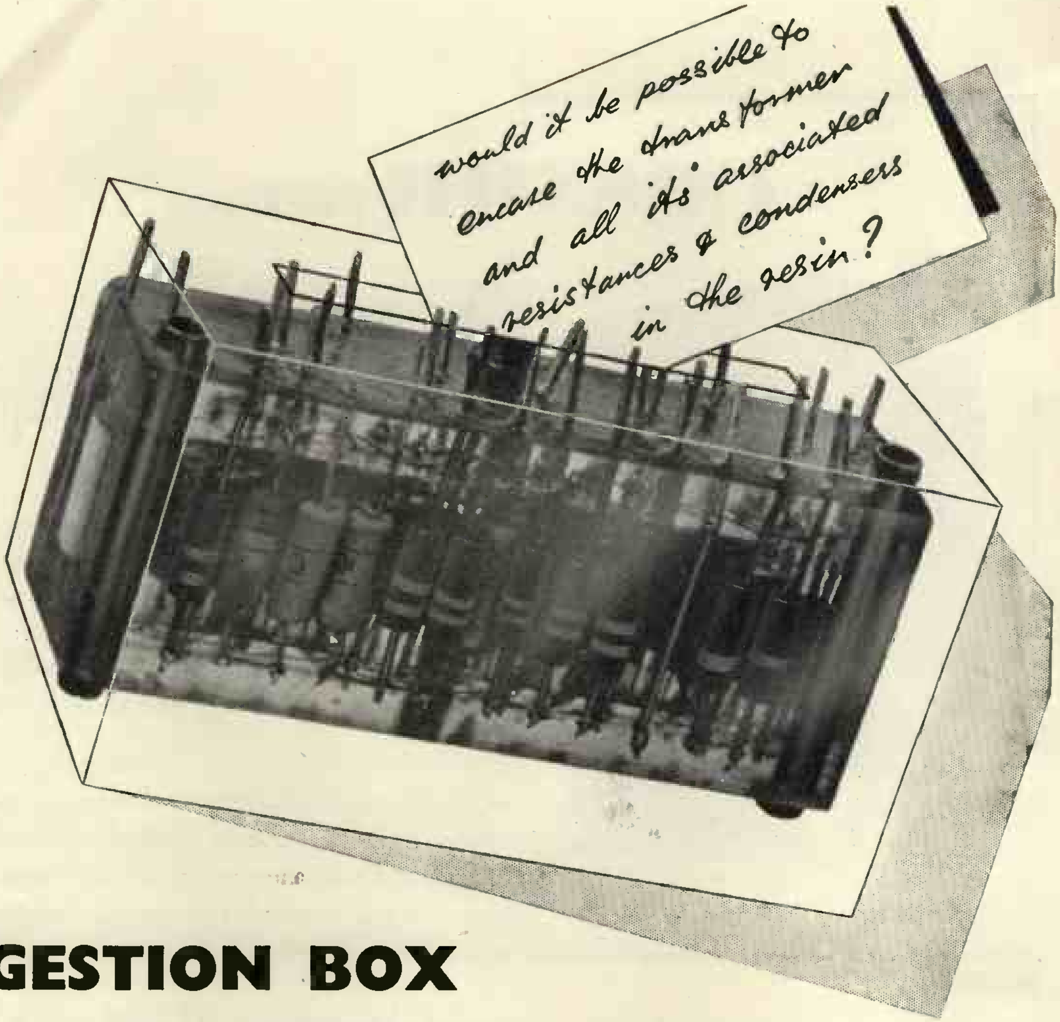
ALWAYS USE COSSOR TUBES & VALVES

Cl.53

Write for illustrated leaflets about both of these instruments

A. C. COSSOR LTD., INSTRUMENT DIVISION, DEPT. 2,
HIGHBURY GROVE, LONDON, N.5

Telephone: CANonbury 1234 (33 lines). Telegrams: Cossor, Norphone, London. Cables: Cossor, London.



SUGGESTION BOX

Take a closer look at this! It may be full of suggestions for solving *your* problems. An intricate electronic circuit is embedded in BAKELITE Polyester Resin, SR.17449—the grade specially recommended for 'potting' circuits.

This resin has not only exceptionally high resistance to shock but it also protects delicate components from heat, humidity and corrosion. It is one of a group of BAKELITE Polyester Resins whose many different properties are being used in a wide range of applications.

It may be that this suggests ways in which Polyester Resins could be of service to you. If so, please 'phone or write to Bakelite Limited, who will be delighted to give you every assistance in following up new ideas.

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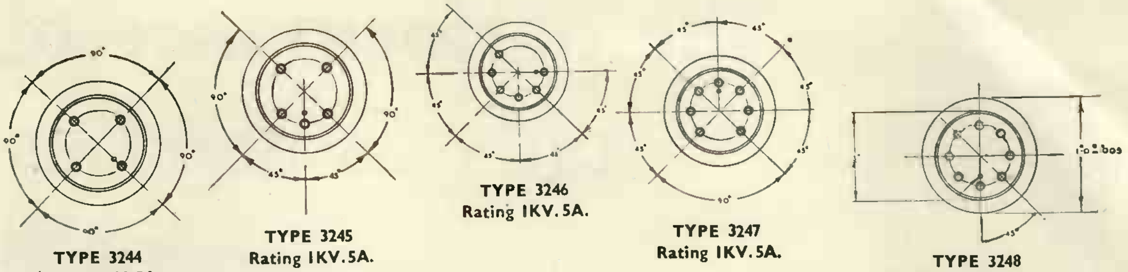
Producers of Phenolic, Urea, Alkyd & Silicone Moulding Materials · Polyester Resins · Phenolic & Urea Resins, Cements & Adhesives · Laminated Sheet, Rod & Tube · Glass Fibre & Asbestos Laminates · Rigid & Flexible PVC Sheet · PVC Moulding & Extrusion Compounds · Decorative Laminated Plastics

P.67



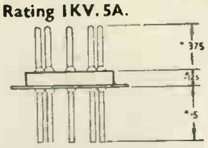
TYPE 3244
Rating 1KV.5A.

TYPE 3245
Rating 1KV.5A.

TYPE 3246
Rating 1KV.5A.

TYPE 3247
Rating 1KV.5A.

TYPE 3248
Rating 1KV.5A.

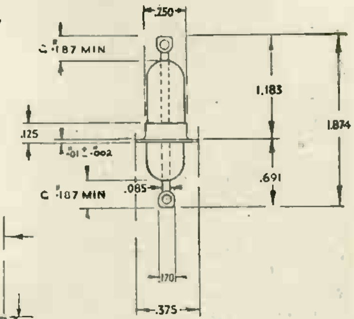


Side view 3244-8

NOTE: All pins are ".04/25. Top Ends Rounded Spaced on ".5 PDC.

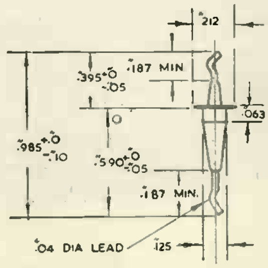
EDISWAN *metal glass seals*

These outline diagrams illustrate a range of Ediswan metal-glass seals delivery of which can be effected promptly. Many additional types can be supplied by arrangement, and our Engineers will welcome the opportunity of collaborating with you in the design of special seals for your particular requirements.

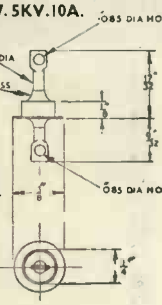


TYPE 252
Rating 7.5KV.10A.

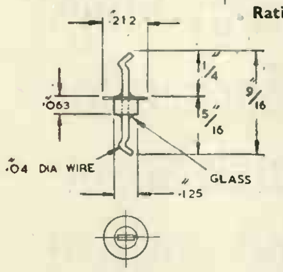
TYPE No.	VOLTAGE RATING (Volts)	CURRENT PER TERMINAL (amps)	REMARKS
252	7,500	10.0	
3279	2,000	10.0	
3167	10,000	10.0	
3183	2,500	5.0	
3244	1,000	5.0	Voltage between pins and flange.
3245	1,000	5.0	
3246	1,000	5.0	
3247	1,000	5.0	
3248	1,000	5.0	
3280	750	5.0	



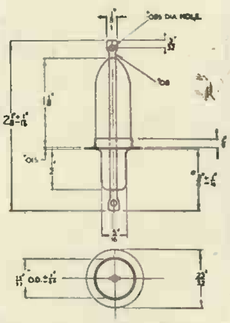
TYPE 3183
Rating 2.5KV.5A.



TYPE 3279
Rating 2.0KV.10A.



TYPE 3280
Rating 750V.5A.



TYPE 3167
Rating 10KV.10A.

EDISWAN

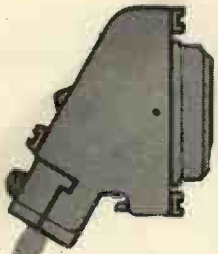
For full information please write for publication R.1602

RADIO DIVISION

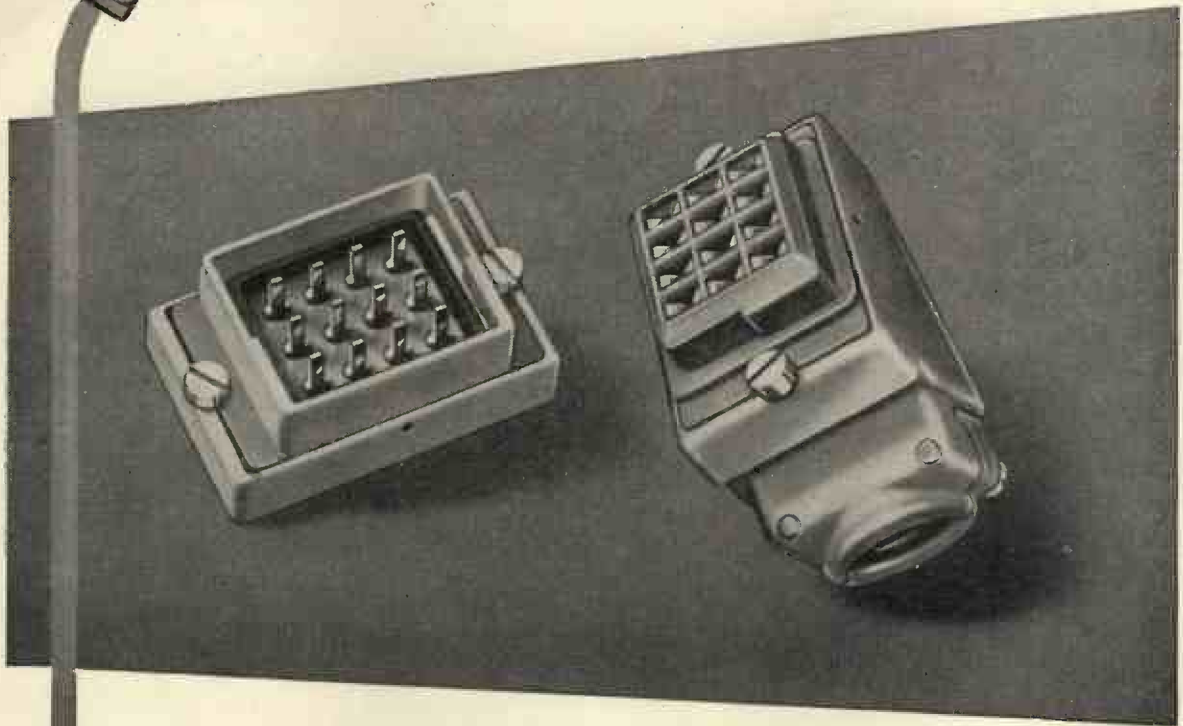
THE EDISON SWAN ELECTRIC CO. LTD., 155 CHARING CROSS RD., LONDON, W.C.2

Telephone: Gerrard 8660 *Member of the A.E.I. Group of Companies* *Telegrams: Ediswan, Westcent, London*

MG104



The performance of only as good as



Multiway Plugs and Sockets for quick action and positive contact

These reliable Plugs and Sockets, proved in service, provide a quick positive connection for up to 28 terminations. They need lower insertion pressure per contact than any comparable product, and when fully mated a dust and damp proof seal is provided between Plug and Socket. Considerable latitude in matching can be allowed when they are used in rack mounting applications.

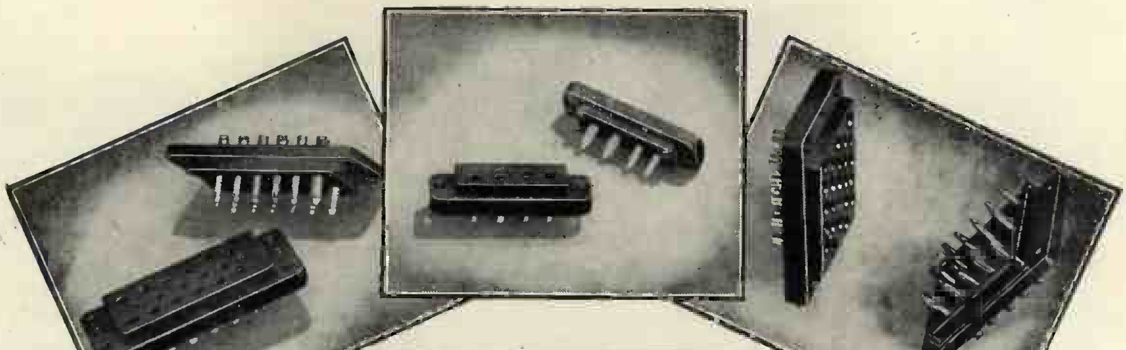
These components are in regular use by :— The English Electric Co. Ltd., Messrs. Marconi's Wireless Telegraph Co.Ltd. and Messrs. Standard Telephones & Cables Ltd.

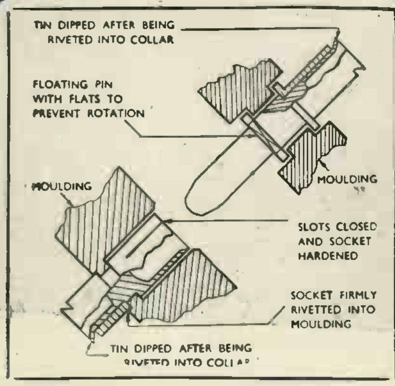
4 WAY **8 WAY** **12 WAY** **20 WAY** **28 WAY**

PLEASE WRITE FOR FURTHER DETAILS TO

'UNITORS'

A range of miniaturised connectors by "Belling-Lee"





4 to 25-WAY FROM STOCK

"Unitors" are links in the chain of electronic events. Any weakness means failure, and perhaps disaster. "Belling-Lee Unitors" are approved by A.I.D. and A.R.B., and have Joint Service Approval.

In recent independent tests, five pairs of 12-way "Unitors" made 16,335 insertions and withdrawals and were still serviceable.

The test apparatus was rigged in such a way that the plug portion was offered up to the socket with the pins at the maximum limit of float, and individual pins approached the relevant socket at various angles.

A coupling comprises a block of plugs and a second block of sockets, arranged so as to be non-reversible. Round pins are employed, turned from high grade brass, silver plated. The normal pins carry 3 amp., but each block has two large pins or sockets to carry 10 amp. All pins are fully floating, and the method of assembly is the subject of a patent.

Resilient sockets are of differentially hardened beryllium copper. All contacts, plugs and sockets are numbered on the face and reverse sides of the body. The distance between flanges when plugged together is 0.281 in.

U.K. PAT. 649,739.

SWISS PAT. 277,799.

A cable cover for line connection is available, together with retainer for chassis mounting.

LIST NO.	PINS
L.653/P&S.	4
L.654/P&S.	8
L.655/P&S.	12
L.656/P&S.	18
L.657/P&S.	25

BELLING & LEE LTD

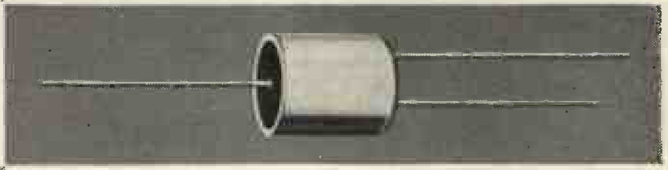
GREAT CAMBRIDGE ROAD, ENFIELD, MIDDX., ENGLAND

NEW low voltage point contact transistor

G.E.C. GET2

This new G.E.C. Transistor, now generally released, has been specially designed for low voltage operation. Similar in dimensions and construction to the GET1, it differs from it in having a higher current gain and a collector dissipation limited to 75mW. The characteristics of the GET2 make it particularly suitable for use with computers, production test limits having been chosen with this application in view.

The GET2 is generally available to all classes of users List price £1.17.6.



The GET1 is continuing in production but supplies are restricted to Equipment Makers and Government Departments. The price has been substantially reduced and is available on application.

Full technical information may be obtained on request from . . .

The Osram Valve and Electronics Department

THE GENERAL ELECTRIC CO. LTD., MAGNET HOUSE, KINGSWAY, W.C.2.

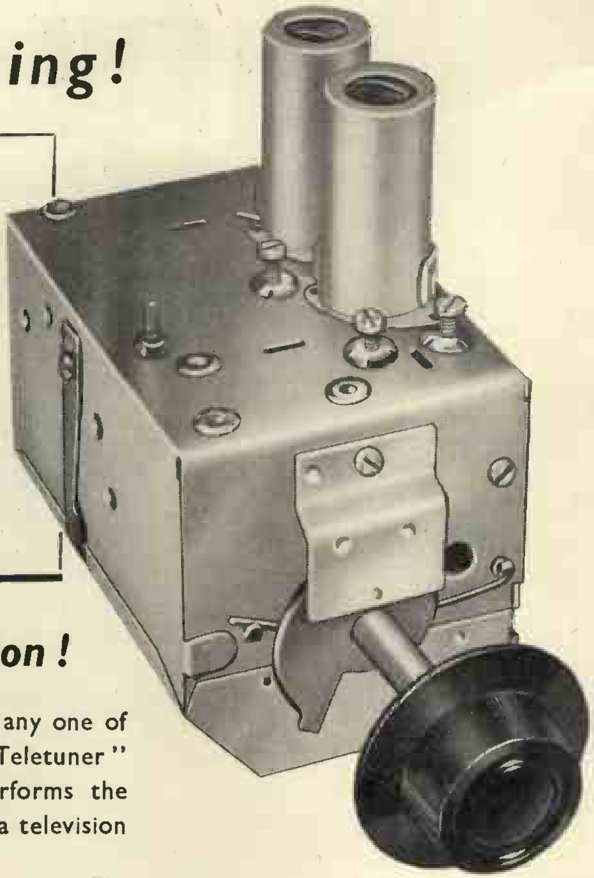
Multi-channel tuning!

Cyldon

"TELETUNER"

(TRADE MARK)

Type TV.12



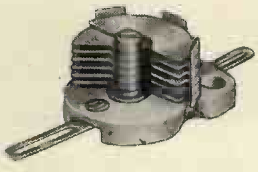
Instant, single-knob selection!

Select a frequency in the 50-220 Mc/s range—select any one of twelve in fact—and this new Cyldon Multi-channel "Teletuner" will handle it. This compact two valve unit performs the functions of R.F. amplifier and frequency changer in a television receiver. ***Write for Folder TV 1953.***

FOUR NEW TRIMMERS

by the Makers of "Cyldon" Trimmers and Variable Capacitors

No. 26. Mica Compression Trimmer.



No. 28. Air Spaced Trimmer.

No. 29. Glass Trimmer.

No. 30. Ceramic Trimmer.

Full details and specifications available on application

SYDNEY. S. BIRD & SONS, LTD. *Contractors to Ministry of Supply, Post Office, and other H.M. Government Depts.*

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IT STANDS ALONE
The New Pack Set type 46
B.C.C. VHF Communications Equipment stands alone in its class. Unequalled performance and reliability is combined with ease of maintenance and simplicity of operation.
B.C.C. sets the standard for reliability and efficiency.

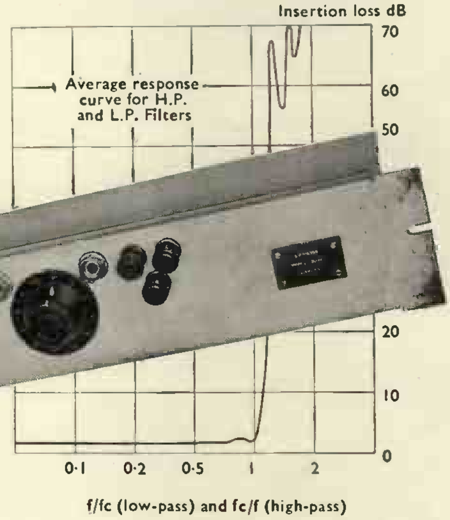
Improved high and low pass filters

TEN CUT-OFF FREQUENCIES IN ONE COMPACT PANEL

These Mullard variable cut-off filters, originally developed in conjunction with the British Post Office, represent a marked advance in filter technique. New design features together with the use of Ferroxcube pot cores have resulted in a valuable reduction in panel size, as well as high attenuation characteristics outside the passbands. Frequency ranges are controlled by a single selector switch—an especially important facility in frequency analysis.

The ten cut-off frequencies of the high pass and low pass filters are so arranged that the filters may be used in pairs to provide very narrow frequency samples.

Brief technical details of the Mullard filters at present available are given here; communication engineers and research workers who may require more comprehensive information are invited to apply to the address below.

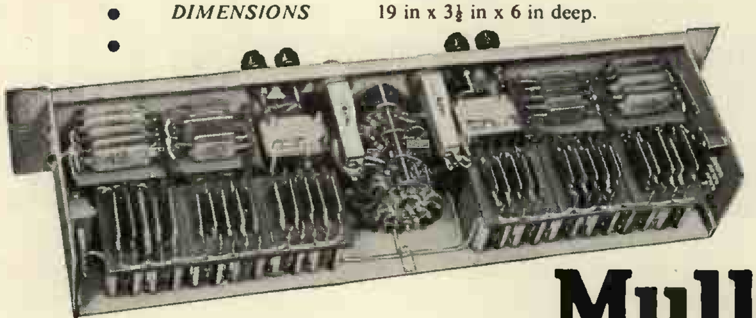


High-Pass Filters (Type GFF.001/02)

CUT-OFF FREQUENCIES (fc)	440, 660, 990, 1480, 2222, 3333, 5000, 7500, 11250, 16800 c/s selected by 10-way switch
IMPEDANCES	Input and output 600 ohms, balanced or unbalanced
STOPBAND ATTENUATION	At 0.8 x fc—50 dB At 0.6 x fc—60 dB
PASSBAND ATTENUATION	3dB ± 1 dB from 1.1 x fc to 20 or 25 kc/s depending on cut-off frequency (fc)
DIMENSIONS	19 in x 3½ in x 6 in deep.

Low-Pass Filters (Type GFF.001/01

CUT-OFF FREQUENCIES (fc)	400, 600, 900, 1350, 2025, 3040, 4500, 6830, 10250, 15400 c/s selected by 10-way switch
IMPEDANCES	Input and output 600 ohms, balanced or unbalanced
STOPBAND ATTENUATION	At 1.25 x fc—50 dB At 1.35 x fc—60 dB
PASSBAND ATTENUATION	2dB ± 1dB from 50 c/s to 0.9 x fc
DIMENSIONS	19 in x 3½ in x 6 in deep



Mullard

SPECIALISED ELECTRONIC EQUIPMENT

MULLARD LTD., EQUIPMENT DIVISION, CENTURY HOUSE, SHAFTESBURY AVENUE, LONDON, W.C.2

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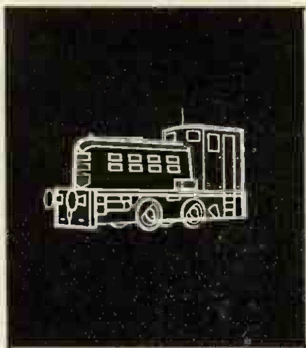
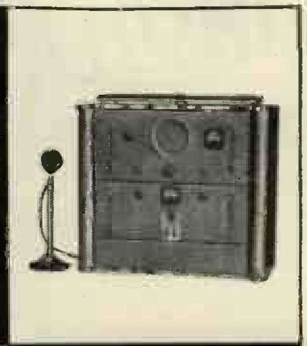
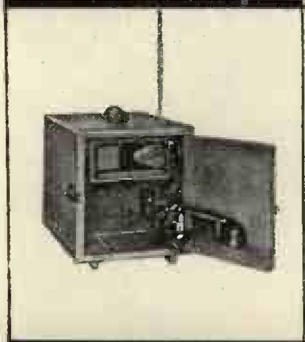


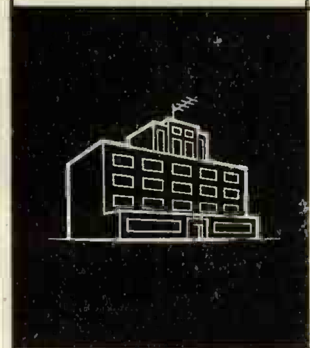




the right move . . .

In more than fifty countries Pye radio-telephones are indicating the right move. The next step, great or small, in divers undertakings.

In civil engineering immediate direct communications are vital. The deployment of resources to the fullest advantage demands contact. Contact swift and sure. Contact at speeds to match the action required.

Wherever men and machines are on the move Pye V.H.F. Radio-telephones will promote speed and efficiency.

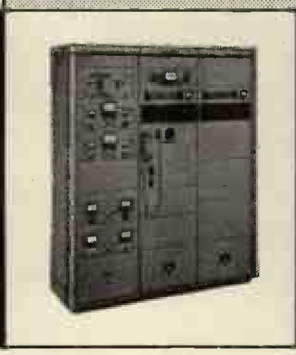
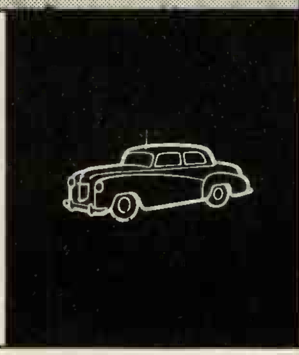


PYE

Telecommunications

CAMBRIDGE ENGLAND

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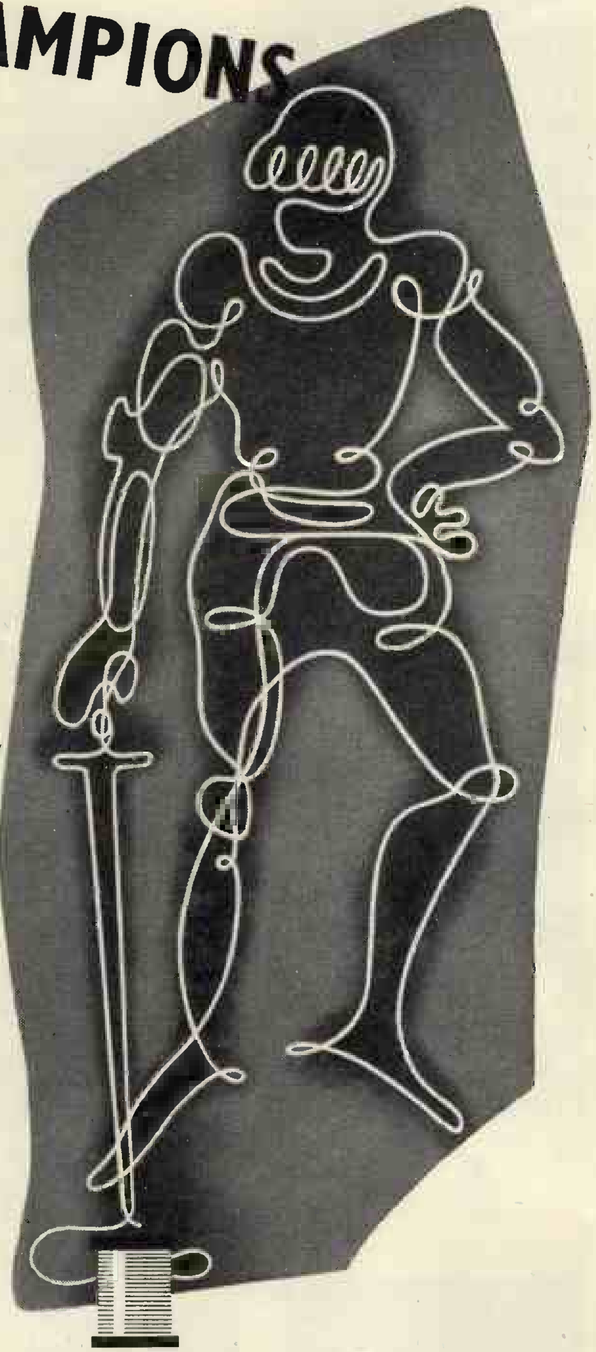

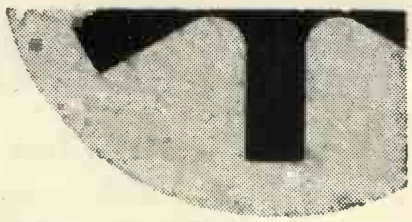

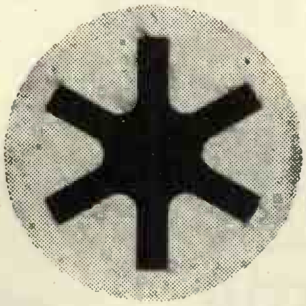

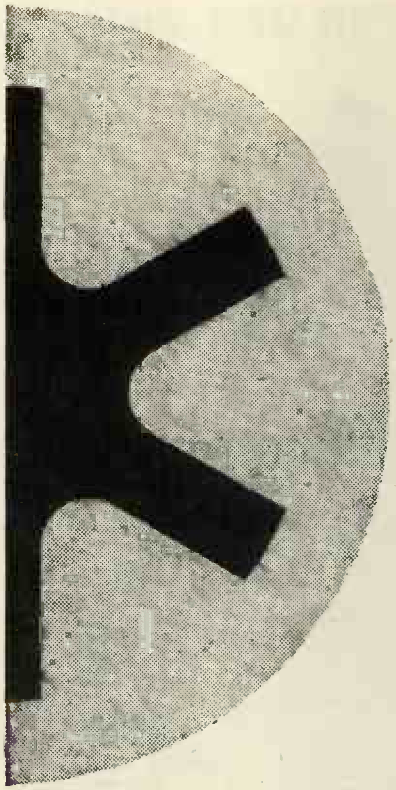

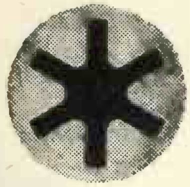

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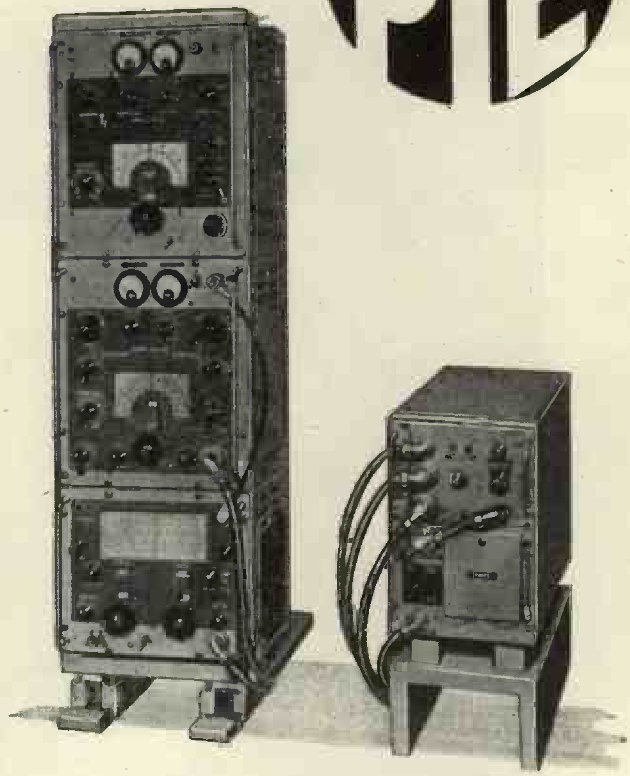

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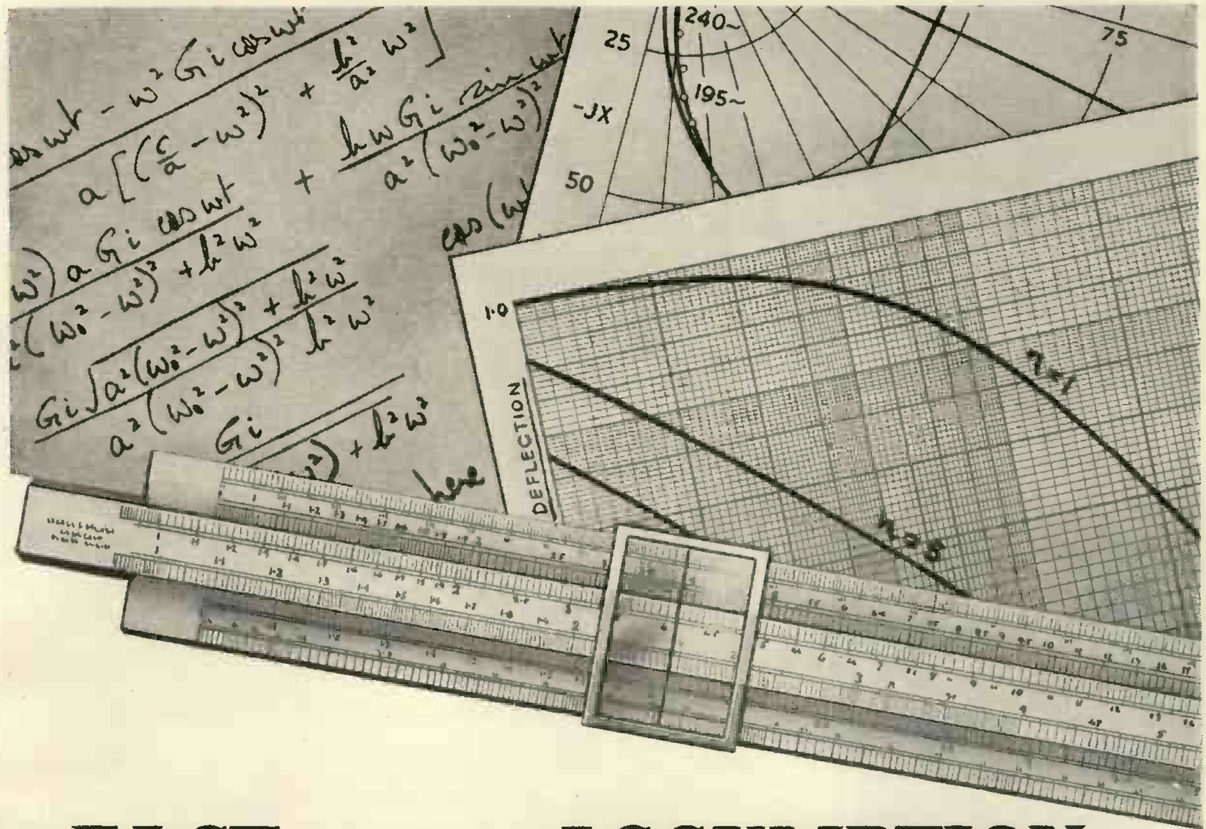

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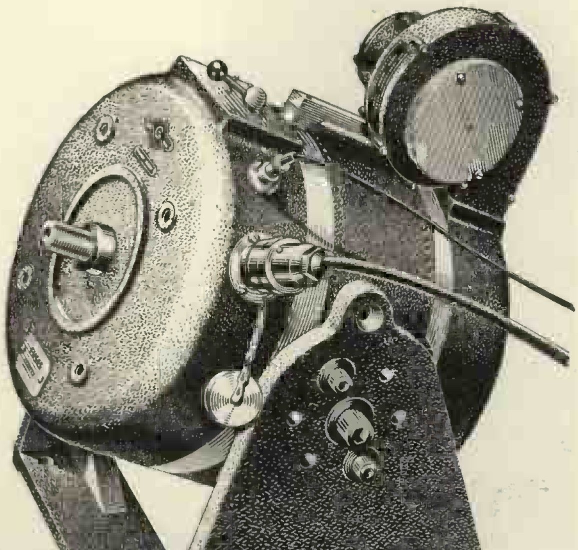

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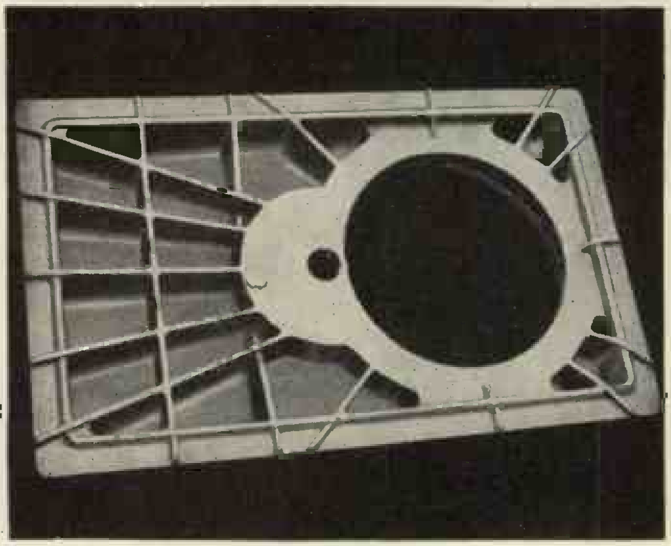

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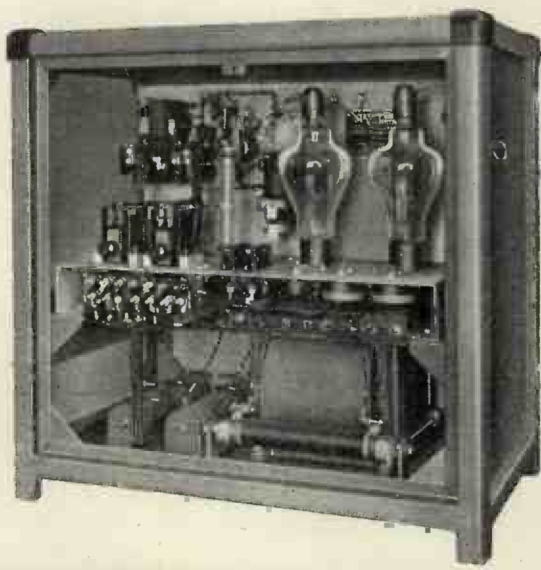

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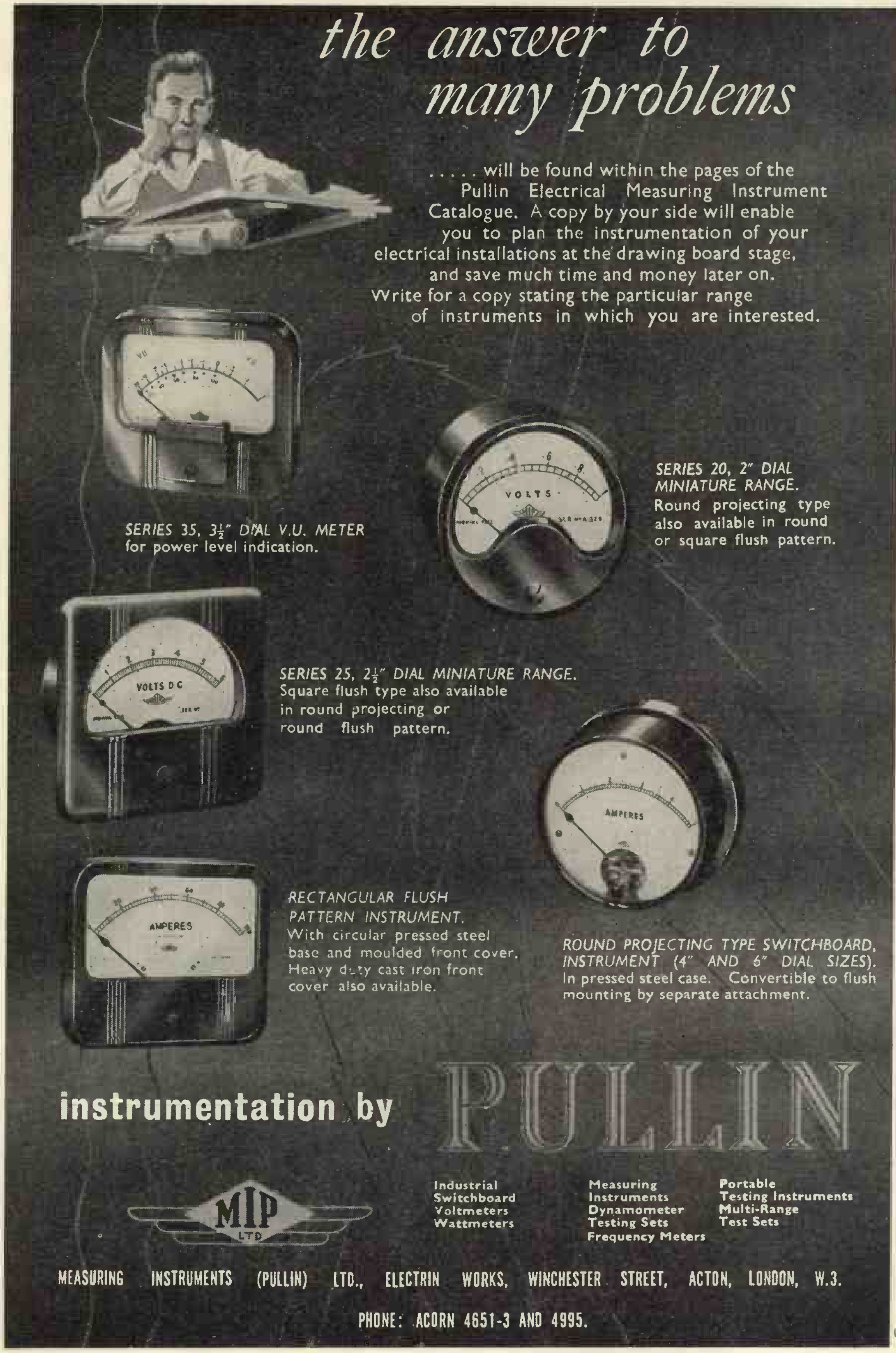
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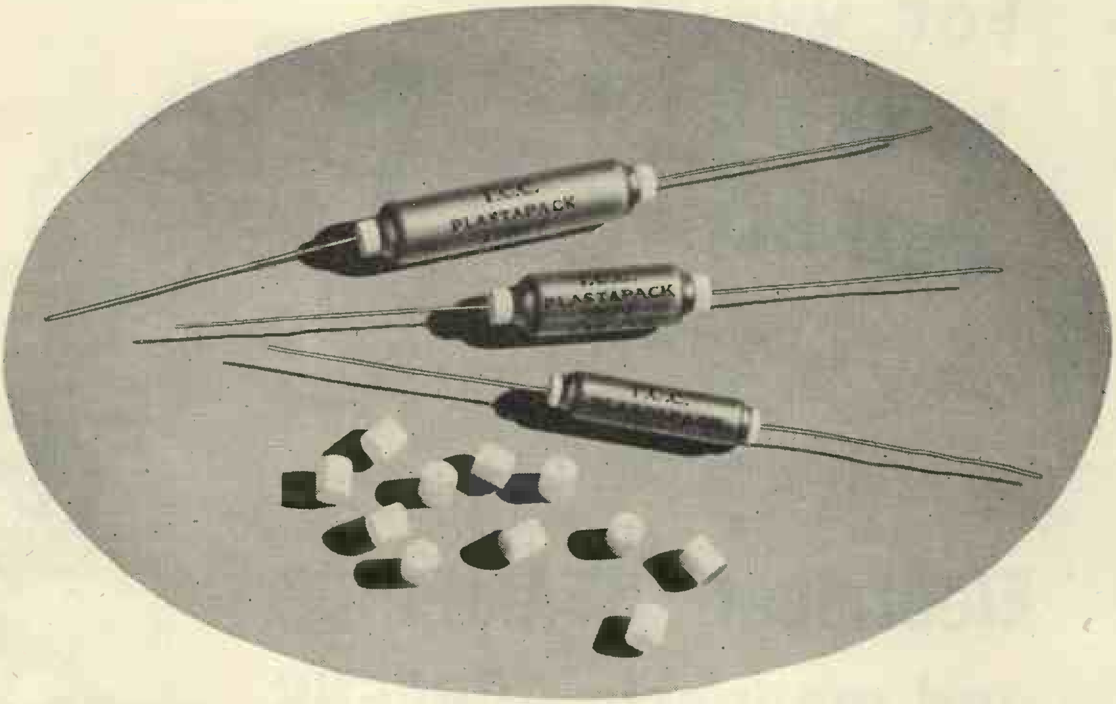

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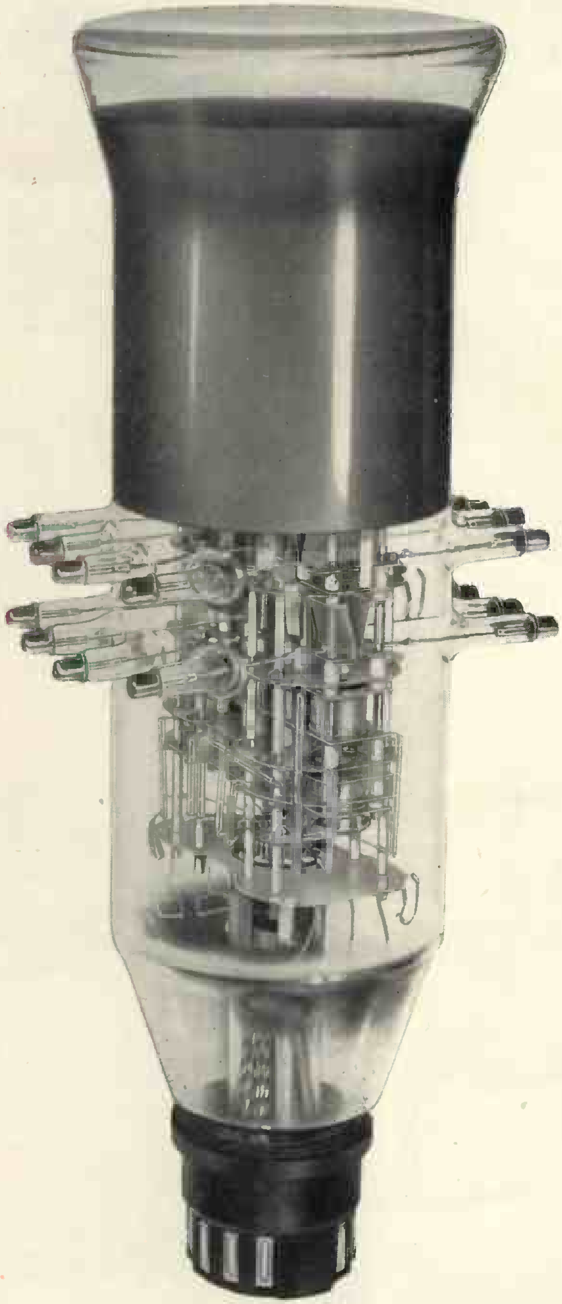

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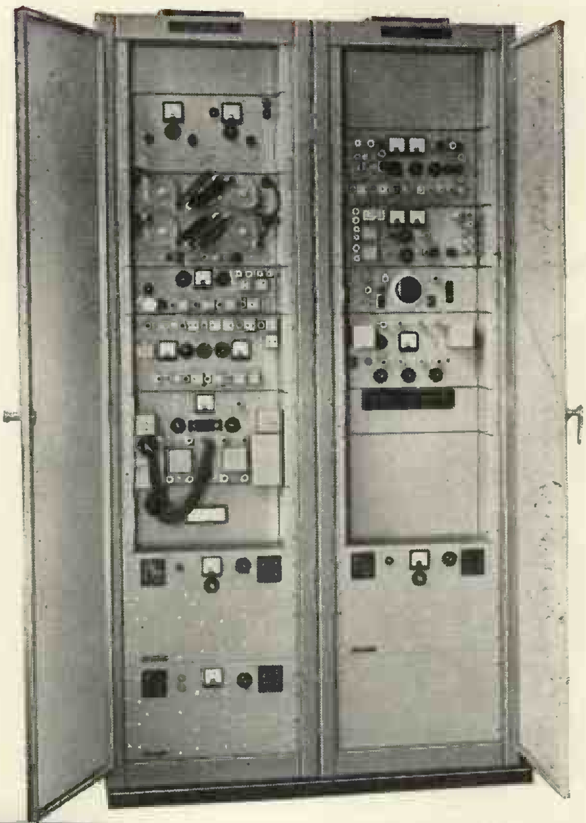

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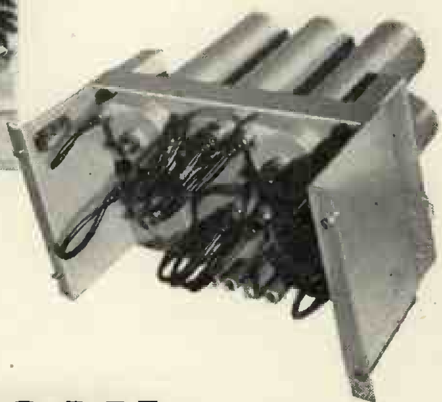

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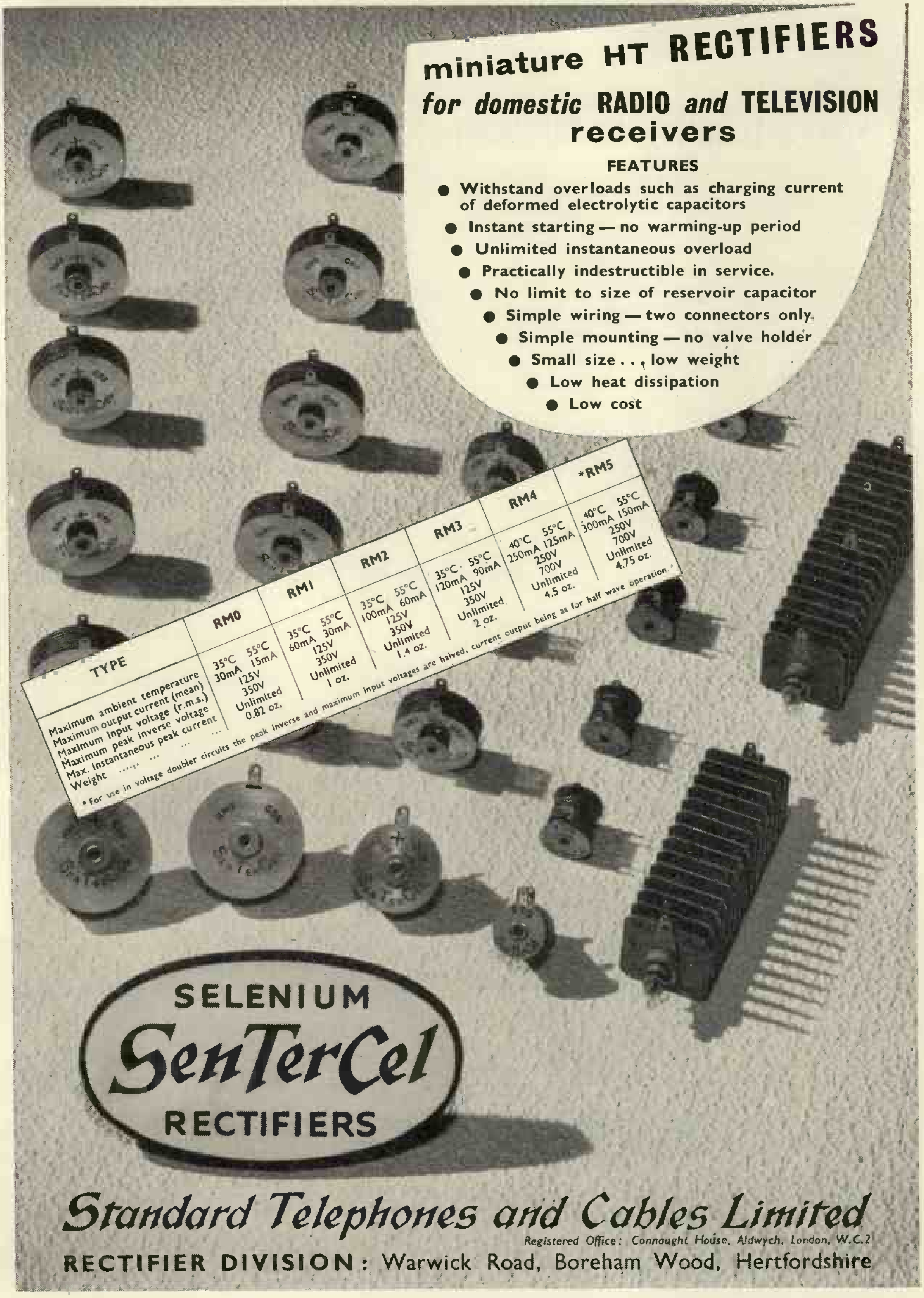
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Maximum ambient temperature	35°C 55°C	35°C 55°C	35°C 55°C	35°C 55°C	40°C 55°C	40°C 55°C
Maximum output current (mean)	30mA 15mA	60mA 30mA	100mA 60mA	120mA 90mA	250mA 125mA	300mA 150mA
Maximum input voltage (r.m.s.)	125V	125V	125V	125V	250V	250V
Maximum peak inverse voltage	350V	350V	350V	350V	700V	700V
Max. instantaneous peak current	Unlimited	Unlimited	Unlimited	Unlimited	Unlimited	Unlimited
Weight	0.82 oz.	1 oz.	1.4 oz.	2 oz.	4.5 oz.	4.75 oz.

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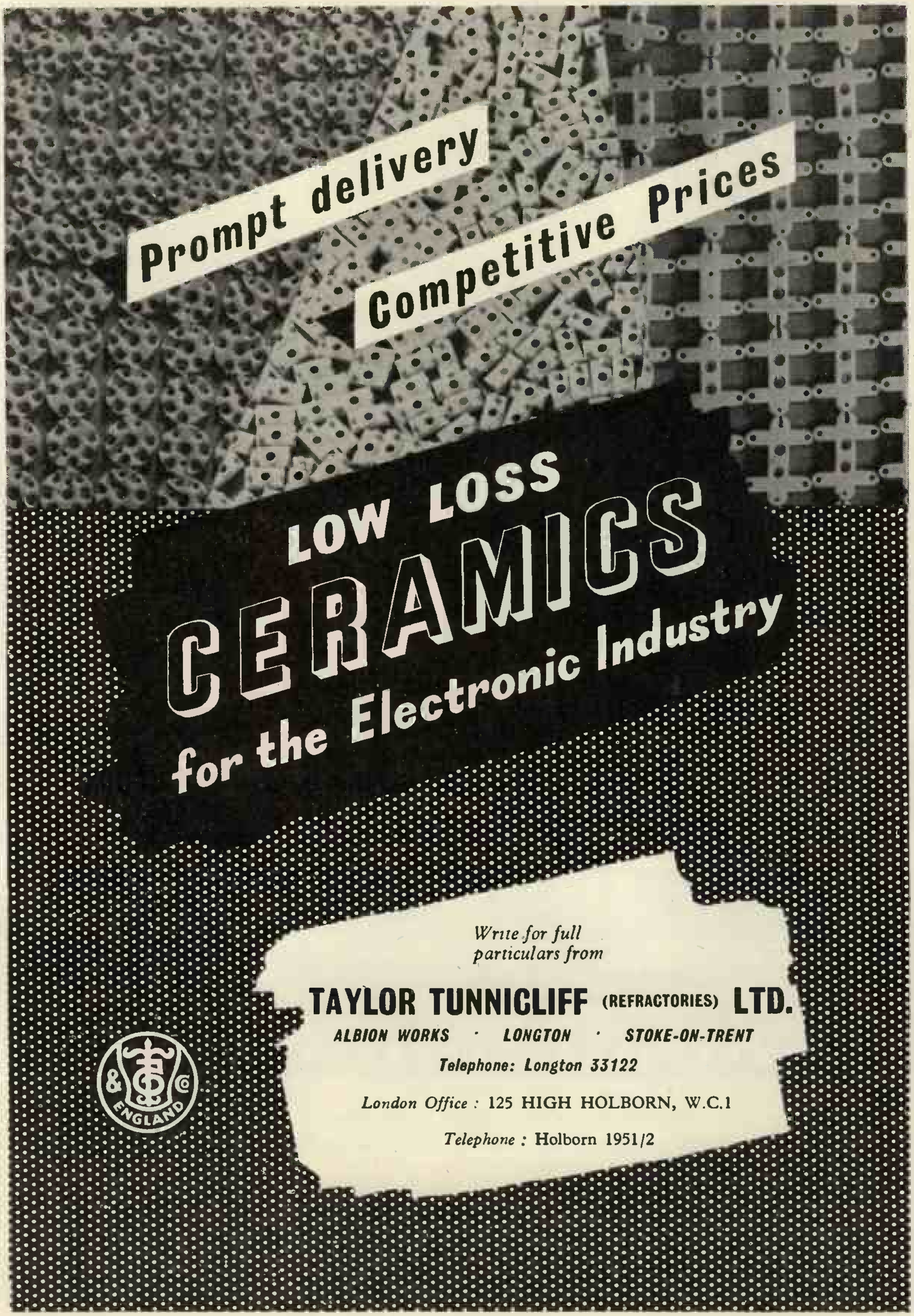
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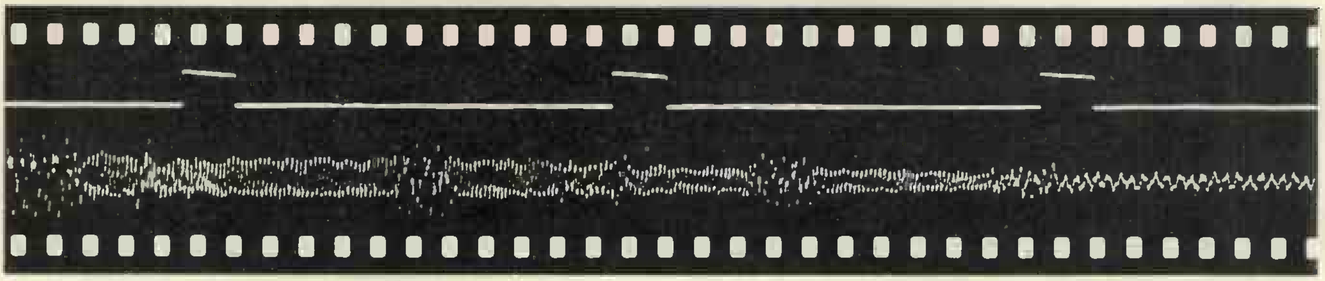

The oscillograph film shows the actual output and input of a P.C.F.S. converter under working conditions, with typical interference and noise levels

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Electronic Engineering

Incorporating ELECTRONICS, TELEVISION and SHORT WAVE WORLD.
Managing Editor H. G. Foster, M.Sc., M.I.E.E.

Vol. XXVI JUNE 1954 No. 316

Contents

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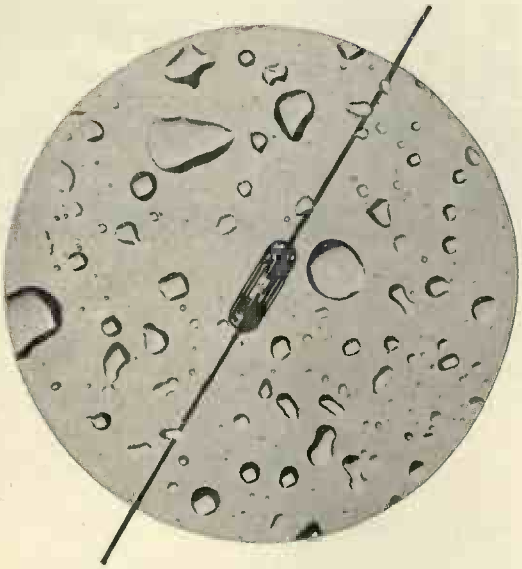


ELECTRONIC ENGINEERING

VOL. XXVI No. 316

JUNE 1954

High Frequency Communications

IT is almost exactly sixty years since a young man, then barely twenty years of age, began to experiment with induction coils and Hertzian oscillators in the garden of his father's house near Bologna. With the enthusiasm of youth and a vision as yet undimmed by the disappointments and frustrations which experience so often brings, young Marconi believed that these new electric waves could be used for practical signalling. From the very outset, Marconi's aim was directed towards the development of *communication* and, as evidence of his tenacity and daring, we have but to recall that within seven years he was sending messages by wireless across the Atlantic.

In recent years, all the excitement associated with discovery and new development has tended to focus interest on the fields of V.H.F., television, radar, electronic calculators and other pulse techniques. Special meetings and conventions have been held to discuss such developments, and this journal has devoted special issues to reviews of their progress but, in so directing attention to these fascinating branches of the radio tree, there has been, maybe, some chance of neglecting, or even forgetting, the far more substantial roots and trunk which are represented by conventional H.F. radio communication. One is apt to forget that H.F. installations still account for some 70 per cent of the capital investment in radio equipment and to overlook the technical, economic and social importance of this more conventional field.

In recognition of this tendency to neglect the field of H.F. communications and in order to lessen the risk of forgetting its fundamental importance, it has been decided to devote this issue of ELECTRONIC ENGINEERING to a review of present practice and a consideration of the special problems which still face the radio communications engineer.

Almost all the outstanding problems seem to arise in consequence of the strictly limited band of frequencies which is, in fact, available for medium- and long-distance radio communication. Although convention may include the whole range from 3 to 30Mc/s within the H.F. band, the behaviour of the ionosphere and the vagaries of propagation very substantially reduce these limits and there cannot be the slightest doubt that the available bands have now become seriously congested. Even though it be granted that complete acceptance of a world-wide agreement on frequency allocations would effect an enormous improvement, there would still remain a great and growing need for severe limitation of the bandwidths occupied by individual transmitters. There is, we believe, a vital need for the development of medium and high-power transmitters in which the design effectively prevents the radiation of unnecessary sidebands.

In recent years, there has seemed to be a marked tendency for users of the H.F. band to use higher and yet higher power in an attempt to drive through the clutter of interference which is so largely caused by frequency "spreading" and the use of inefficient keying methods. The logical consequence of this deplorable tendency can only be a shouting match in which none but the loudest can make himself heard, and in order to discourage such an unseemly contest, the need for development of improved transmitters is imperative.

Although limitation of the bandwidth occupied by individual transmitters will go a long way towards a reduction of the present congestion, there is little doubt that a further and very substantial contribution could be made by improvement in the design of aerial systems. Far too often today a major proportion of the transmitter power is radiated in side lobes which contribute nothing to the signal strength at the receiver, but which add enormously to the world-wide level of interference. It is thirty years since Franklin developed the beam array which caused such a revolution in the plans for the system of Imperial communications; yet, in the intervening years no better solution has appeared to the problem of concentrating the radiated energy into a narrow beam, focused sharply on to the receiver.

Let us recognize, then, that there are still major technical problems of immense importance to be solved in the field of H.F. communications. Let us remember that this field accounts for the largest proportion of capital investment in our industry, and for a large share of the export market in radio equipment. We may then appreciate the real importance of the H.F. communications in our current economy and be prepared to devote a more lively interest and technical effort into a solution of the outstanding problems which still confront us. It is with these thoughts in mind that this issue of ELECTRONIC ENGINEERING is presented.

COMMONWEALTH

RADIO COMMUNICATION SERVICES

By D. Scott *

A brief history of the growth of the Commonwealth Communication Services and an account of some of the problems to be faced in the future.

IN Commonwealth, as indeed in World Communications, telegraphy pioneered the introduction of high frequency radio techniques, telephony and broadcasting following as the possibilities of the new medium became more fully appreciated.

It is fitting therefore that since an article of this length cannot deal adequately with three such comprehensive services it should confine itself to an outline of the origins and subsequent development of Commonwealth high-frequency radio-telegraph services.

In July 1924 the Marconi Company signed contracts with the British Government and the Dominions of Australia, Canada, India and South Africa for the construction of radio stations of what was then an entirely new design, capable of providing telegraph circuits having a traffic capacity greatly in excess of anything hitherto known in the sphere of long-distance point-to-point communications. By the end of 1927 when the fourth and last of these circuits, that between London and Bombay, had passed its acceptance tests and gone into commercial operation it was apparent that a revolutionary advance had taken place in the history of telecommunications.

Other nations besides Great Britain had, of course, been experimenting with short-waves; both the United States and Germany were, in fact, operating commercial short-wave services over very considerable distances as early as 1925, and much operational data were being compiled and studied. The indications were, however, that the signals were too erratic in their behaviour to be of any great commercial use, and the attitude of American engineers towards the use of high frequencies for main communication channels has been described as one of "interested scepticism." It was only in this country that the proper significance of directional transmission and reception was appreciated, and there is no doubt whatever that C. S. Franklin's "Beam" aerial, more than any other single factor, accounted for the spectacular success of the Commonwealth telegraph circuits, a success which naturally attracted universal attention to the possibilities of the new medium not only for telegraphy, but for radio-telephony and broadcasting.

The "Beam Wireless Services," as these original Commonwealth H.F. services came to be known, were at first operated in the United Kingdom by the Post Office, and so entered into direct competition with the privately owned submarine cable companies, whose extensive cable networks already served all the Dominions except Canada (Fig. 1).

* *Cable and Wireless Ltd.*

In the above photograph "Electra House" the London headquarters of Cable and Wireless Ltd. can be seen (with Union Flag flying). In the foreground is Captain Scott's ship the "Discovery", while on the skyline can be seen the dome of St. Paul's Cathedral and the spire of St. Bride's Church.

There occurred an abrupt outstripping of "demand" by "supply" in the telegraph domain, and the effect on the traffic receipts of the cable companies was so serious that they were soon in grave danger of economic ruin. Happily such a catastrophe was avoided by Government action. Considering the importance of the cable system to the Commonwealth, not only from the strategic aspect, but also because of its great reliability, the Government brought about a merger between cable and radio interests so that the Commonwealth, after leading the world in this new medium for some two or three years, ceased to have a separate existence of their own; the pattern of their development had thenceforth to be related to the needs of the cable and wireless system as a whole, an unfortunate circumstance from a technical standpoint, as events were soon to prove. Barely had the advantages of a co-ordinated external telegraph system begun to be realized before the economic depression of the 1930's spread over the world,

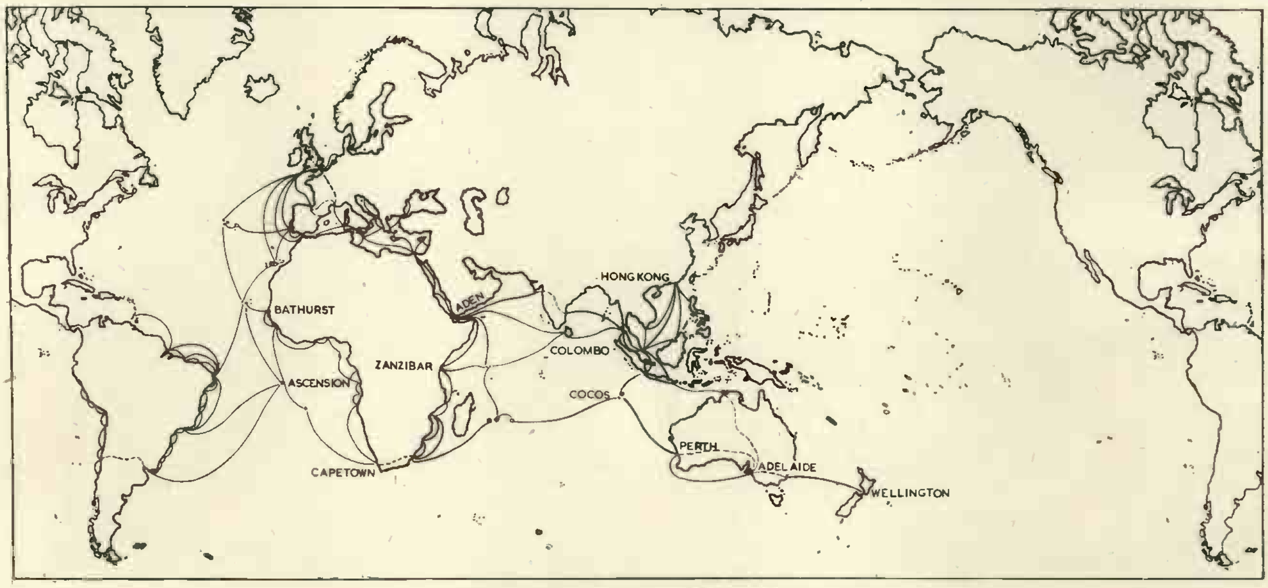


Fig. 1. British cable companies' network, 1929

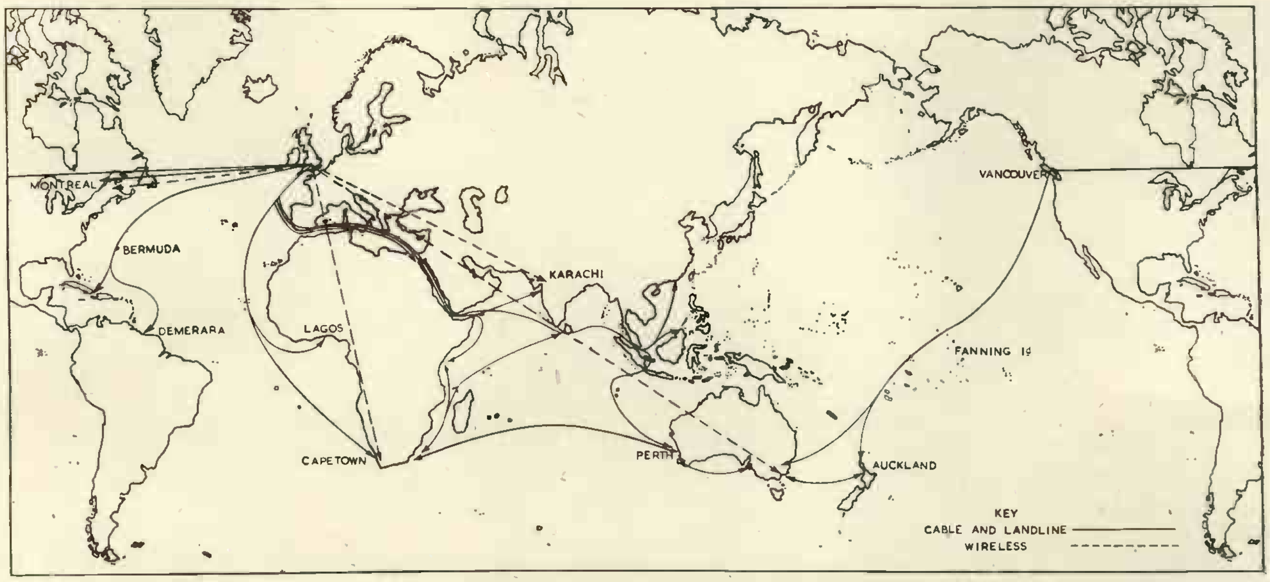


Fig. 2. Commonwealth cable and wireless network, 1930

on 29 September 1929 all the telegraph communications of the Commonwealth and Empire were, by Act of Parliament, placed in the hands of a single operating company, later to become Cable and Wireless Ltd. At the same time a Commonwealth Communications Advisory Committee was set up, with members nominated by the British and Commonwealth Governments, to be responsible for safeguarding strategical needs and to provide some measure of co-ordination of policy.

So it came about that H.F. radio-telegraph services in drastically reducing the interchange of business telegrams, the revenue from which forms the life blood of most communication enterprises. Fig. 2 shows the Cable and Wireless network as it was at this time. With all the main Commonwealth and Empire routes from the United Kingdom served both by cable and by short-wave radio, it was possible to effect substantial operating economies by strictly avoiding all unnecessary duplication of channels. In practice this policy resulted in a drastic curtailment in the use of the radio channels, which tended to be operated only during those hours of the day when their performance was known to be good, and shut down at the onset of periods of difficult route conditions.

From an economic standpoint such an arrangement could not be challenged, but it was not unnaturally deplored by radio engineers faced with the task of probing the mysteries of the ionosphere and deprived of much needed operational data.

However, world trade gradually recovered and by 1938 thirteen additional short-wave circuits were being operated from London, including two new "beam" circuits to Nairobi in Kenya and Salisbury, Rhodesia. Also, in the intervening years, "cables" and "wireless" had learned to live together in harmony, each learning much from the other, and each benefiting from the association. Integration of the two systems had reached an advanced stage (Fig. 3), and Commonwealth communications secured against anything but a major catastrophe, when war was declared in September 1939.

The volume of telegraph traffic to be handled, in particular Government and Press categories, increased enormously, and for a few months the efficiency of the composite system was strikingly demonstrated. Then Italy entered the conflict, and at once cut all the Mediterranean cables between Gibraltar and Malta, interrupting the main cable routes to the Middle East, India, the Far East and Australia. To counter this grievous blow, followed later by the loss of the whole of the Far Eastern cable network to the Japanese, only one course of action was left—the lost capacity had to be recovered through increased use of high frequency radio. Expansion on an unprecedented scale was called for.

New radio circuits were started up between London and such key switching points in the cable system as Gibraltar, Malta, and Aden, in order that as much as possible of the system's pre-war flexibility might be salvaged; new radio circuits were provided for the war-time Dutch, Belgian and French Governments in London to maintain contact

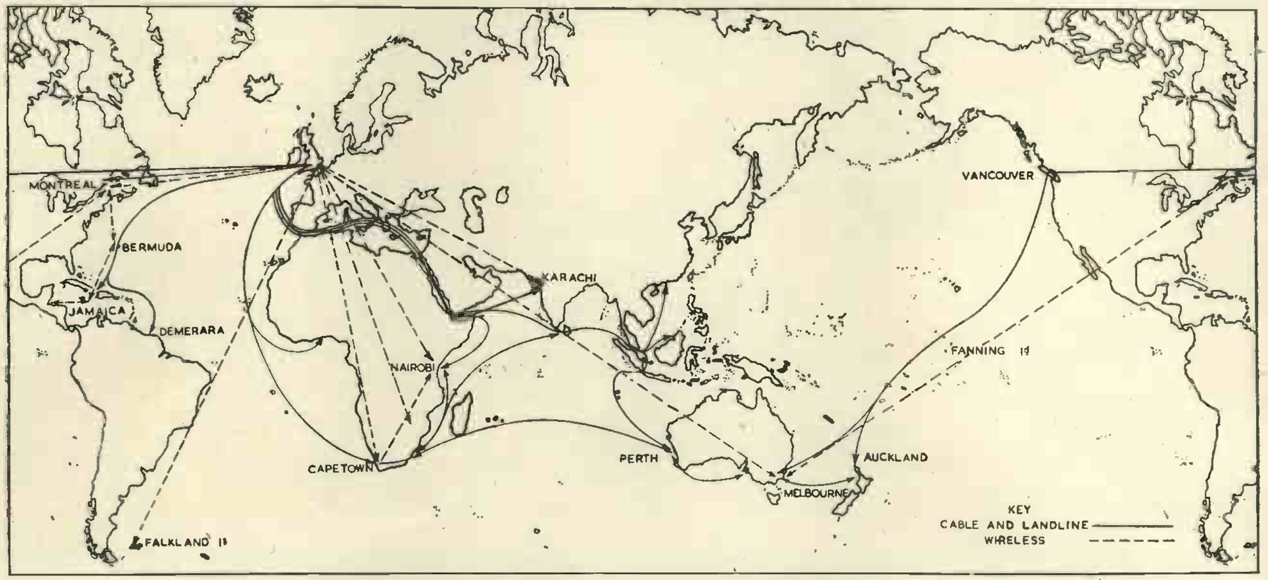


Fig. 3. Commonwealth cable and wireless network on outbreak of war, 1939

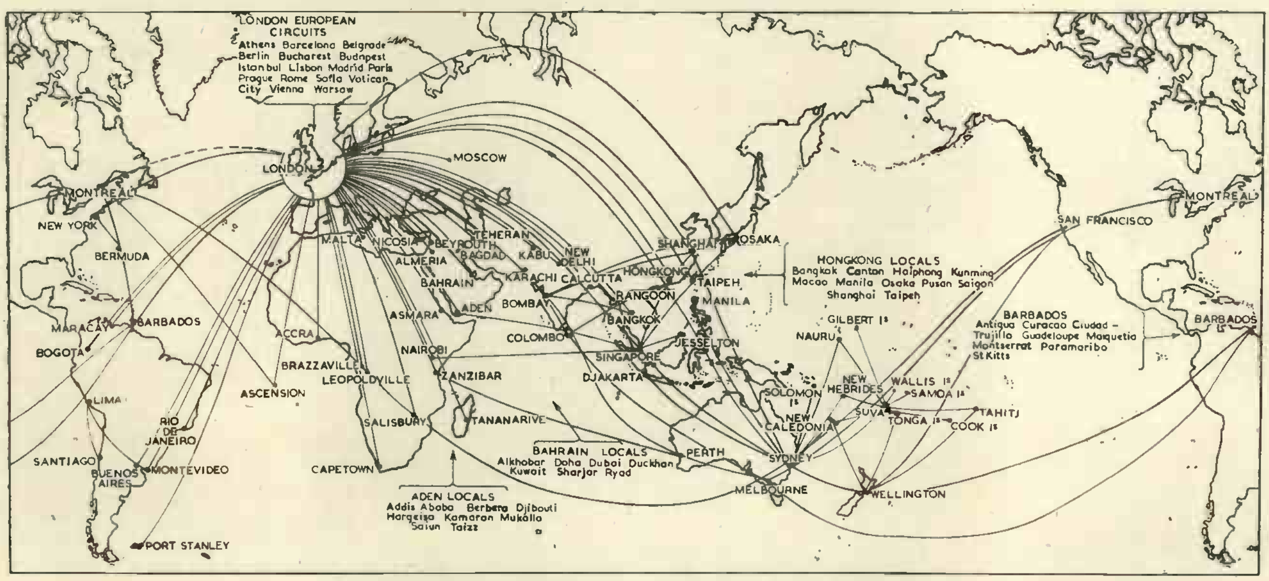


Fig. 4. Commonwealth telecommunications—post-war wireless system

with their loyal overseas territories in the East and West Indies and in Equatorial Africa; new radio circuits were established to handle press traffic from war theatres remote from adequate cable services; and special automatic radio-telegraph relay stations were constructed in Colombo and Barbados to improve the working, and therefore the traffic carrying capacity, of the Australian circuit with London. Fig. 4 shows the effect of this expansion on the Commonwealth and Empire services.

The end of the war brought with it a fundamental change in the organization. Control of the system by the "single operating company" of the 1929 Act of Parliament was no longer considered compatible with the principle of partnership in Commonwealth relationships.

At a Conference in London in 1945 a detailed plan was accordingly drawn up in which the Commonwealth Governments concerned agreed to take into national ownership the external telegraph services in their respective territories, constituting "National Bodies" to assume responsibility for their operation and maintenance.

In the event, the National Bodies which it had been decided could be either a nominated existing Government Department or a specially established public corporation, were constituted thus:

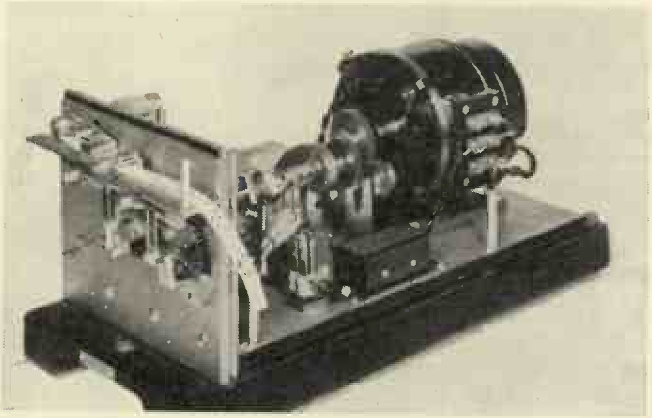
United Kingdom	General Post Office
Canada	Canadian Overseas Telecommunications Corporation
Australia	Overseas Telecommunications Commission (Australia)
New Zealand	Post and Telegraph Department
South Africa	Department of Posts and Telegraphs
India	Ministry of Communications (Overseas Communications Service)
Ceylon	Posts and Telecommunications Department
Southern Rhodesia	Posts and Telegraphs Department

The same 1945 Conference agreed to the setting up of a Commonwealth Telecommunications Board with powers substantially greater than those of the original Communications Advisory Committee of 1929, to co-ordinate future policies and technical developments, with particular emphasis on the continued integration of radio and cable as complementary parts of a balanced system.

The splitting up of the Cable and Wireless Ltd. system and its reorganization under the various National Bodies commenced in 1946 and was substantially completed by 1951. Realizing how much depended on the technical efficiency of this much more loosely knit organization, the Commonwealth Telecommunications Board lost no time in sponsoring a meeting of technical and traffic experts from the United Kingdom, the Commonwealth countries and several of the Colonies. This meeting, the first in the history of Commonwealth Telecommunications was held in London in 1950 and provided the opportunity for a wide range of discussions on technical and traffic policies, and for a comprehensive review of technical advances and research projects likely to have applications in further improving the Commonwealth system.

Some idea of the diversity of technical factors involved in maintaining and co-ordinating the development of Commonwealth radio-telegraphic services may be given by outlining the course of a representative telegram filed London for transmission to, say, Sydney in Australia.

In London, such a message would first be prepared for transmission in the form of a perforated tape, which, on the outgoing Australian circuit, would be fed into one of a pair of automatic transmitters associated with a time-division multiplex system known as double-current cable-code or D.C.C.C. This system, developed by Cable and Wireless Ltd. as part of their aforementioned policy of integrating cable and radio circuits, is operated basically



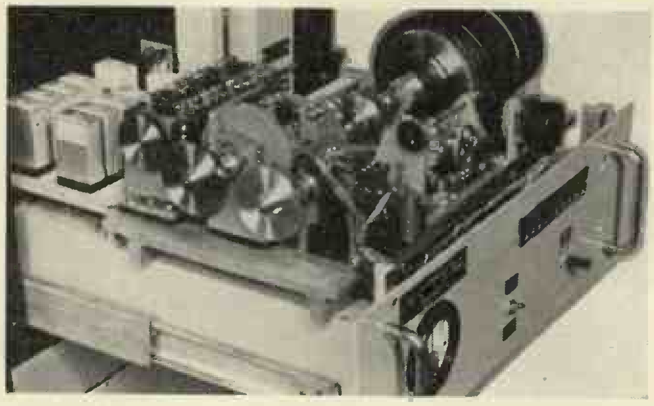


Fig. 5. D.C.C.C. equipment. From top to bottom: Automatic transmitter type A40; D.C.C.C. multiplex sending unit type J12; D.C.C.C. multiplex receiving unit type J13; direct printer type B8

on cable code, a three-positional code using the standard morse alphabet. Two channels, whose speeds may be varied according to radio path conditions and traffic demands, but which commonly work at around 75 words per minute, are combined to produce a two-position aggregate signal capable of being handled over any normal radio-telegraph link.

All the equipment is synchronous, both transmitting and receiving units at each terminal being controlled from a similar constant-frequency source, with the receiving unit having additionally a synchronizing device applying phase correction to hold it in step with the incoming signals. Fig. 5 shows a modern combined transmitting and receiving terminal complete with synchronous drive, and the associated circuit apparatus.

D.C.C.C. was first used to provide direct printing telegraph channels on radio circuits as far back as 1930, when it was applied with conspicuous success to the London-Capetown beam circuit. At present London operates 21 such circuits and there are 22 others elsewhere in the Commonwealth system. In the rest of the world, however, recent years have witnessed a parallel expansion in mechanization by the use of 5-unit teleprinter code on international radio circuits, largely in order to standardize equipment and facilitate direct interconnexion with internal telegraph networks. Because of its inherent liability to character transposition errors when subjected to the violent changes in signal-to-noise ratio encountered from time to time on all high frequency radio circuits, plain 5-unit code has found little favour in the Commonwealth system. The same useful objectives, and also the expansion of subscriber-to-subscriber teleprinter operation, can be better achieved by employing a 7-unit code, of which there are several forms under development. With each character containing the same number of mark and space elements mutilations occurring in transmission are readily detectable at the receiver. Failures can either be indicated in a positive manner by the printing of a special symbol (error-detection) or the scope of the mechanism can be further extended to initiate automatically a request to the transmitting terminal for an immediate repetition of the corrupt character (error-correction). Two such 7-unit systems, one entirely electronic and the other electro-mechanical, are about to go into service on Commonwealth routes. In each case the use of D.C.C.C. time-division channelling equipment will allow one of the two channels to be retained on cable-code, so preserving a valuable feature of the present integrated cable and wireless network—the facility of transferring traffic in perforated tape form from one medium to the other with a minimum of delay.

Returning to the specific case of the telegram to Australia, the aggregate signal from the D.C.C.C. combining unit is used to control one of a group of frequency-modulated voice-frequency channels carried over landline to the selected radio transmitter station, frequency-modulated valve oscillators being used for transmission, limiter-discriminator units for reception and derived type band-pass filters for effecting channel separation. For speeds up to 120 bauds twelve channels, each using a deviation of 50c/s are normally grouped together, with 240c/s spacing between adjacent carriers; for speeds beyond 120 bauds and up to 280 bauds the number of channels per group is reduced to six, with deviation increased to 100c/s and inter-channel spacing 480c/s.

At the United Kingdom transmitter station the signal from the line channel is used to key the radio transmitter allotted to the Australian service. Frequency-shift telegraphy will normally be employed over the radio path, the high-frequency carrier being shifted some 400 to 500c/s between the two positions, space and mark, of the telegraph signal. The appropriate radio frequency for communicating with Melbourne will have been selected, and the transmitter output of 20kW of high-frequency power conveyed via concentric tube transmission line to an aerial array directed on Sydney.

This may be a Franklin beam array, comparatively little changed from the original design which made history in 1926. No other type of directional array has proved more effective in meeting the requirement of long-distance point-to-point circuits for a concentration of radiated energy both in the azimuthal and zenithal planes. Against this, there have to be considered its cost, both initial and maintenance, and the fact that it can be used for only one specific radiated frequency which, at a given time, may not be the optimum frequency for the route. It is customary, when the beam frequency fails, to transfer the service to a correctly orientated rhombic aerial. With this type of transmitting aerial, the polar diagram varies slowly with wavelength, making it suitable for operating over a fairly wide band of frequencies, albeit with some sacrifice of aerial gain. (The gain of a Franklin beam array is of the order of 20-23db over a single vertical half-wave aerial; that of a rhombic is generally assessed at 13-16db.)

Choice of the correct radio-frequency and effective transmitter power for the circuit requires a knowledge of the characteristics of the transmission path via the ionosphere, and of the noise level to be anticipated at the receiving site.

Although Kennelly and Heaviside had earlier postulated the presence of an ionized layer in the upper atmosphere capable of reflecting radio waves, it was not until the period 1925-1927 that the researches of Sir Edward Appleton and his co-workers proved the existence first of a layer about 100 kilometres above the earth designated the E layer, then of a still higher layer termed the F layer.

The opening of the Commonwealth beam circuits coincided then with these first explorations of the ionosphere. Data on the diurnal and seasonal changes of the layers were only beginning to be accumulated, so the early choice of operational wavelengths was largely guided by the "shadow charts" of Tremellen and Eckersley, where the order of radio frequency advocated for a circuit depended on the degree of sunlight or darkness through which the radio wave was to pass on its path from transmitter to receiver.

In 1937 a C.C.I.R. sub-committee on wave propagation was able to report considerable progress in the practical application of data by then available and, recognizing the value to operating agencies of knowing the optimum frequency to use at any given time on any given route, the sub-committee produced distance/frequency curves which can be regarded as the forerunner of modern Prediction Charts.

With the development of the technique of vertically sounding the ionosphere at many different parts of the world—work in which Commonwealth participation has been of such value that at present over thirty ionosphere sounding stations are located on Commonwealth territory—the regular and irregular variations of the layers throughout the day, season and sunspot cycle became apparent. The importance of being able to estimate the atmospheric noise levels on any frequency for any time and any part of the world was also appreciated and as much information as possible collected for the compilation of noise-charts.

In these fields of ionospheric research as in so many others of a technical nature, progress was sharply accelerated during the second World War, with its unprecedented military calls for reliable long-distance communications.

As a result, Commonwealth telecommunication services were by 1946 able to benefit from greatly improved methods of ionospheric forecasting, which facilitated the issuing in chart form of monthly forecasts for specific circuits.

Four examples of United Kingdom (Cable and Wireless) forecasts for the Australian route are grouped together in Fig. 6 to facilitate comparison. Two are for 1947, a sunspot maximum year, and two for 1953, at or near sunspot minimum conditions. The increased difficulties of operating the circuit during the years of low sunspot activity are evidenced by the narrowing of the available frequency band and the virtual closing of the route over long periods of the day.

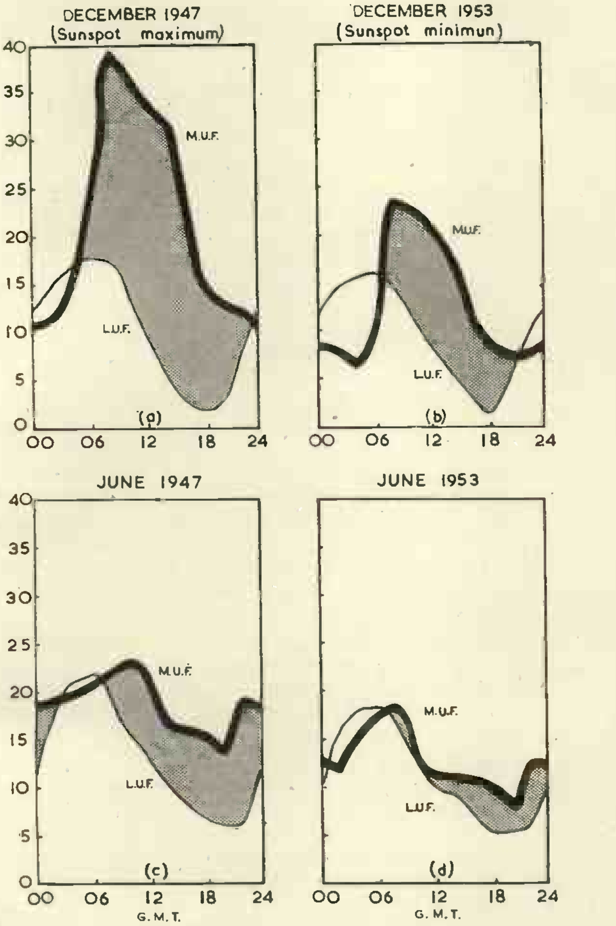


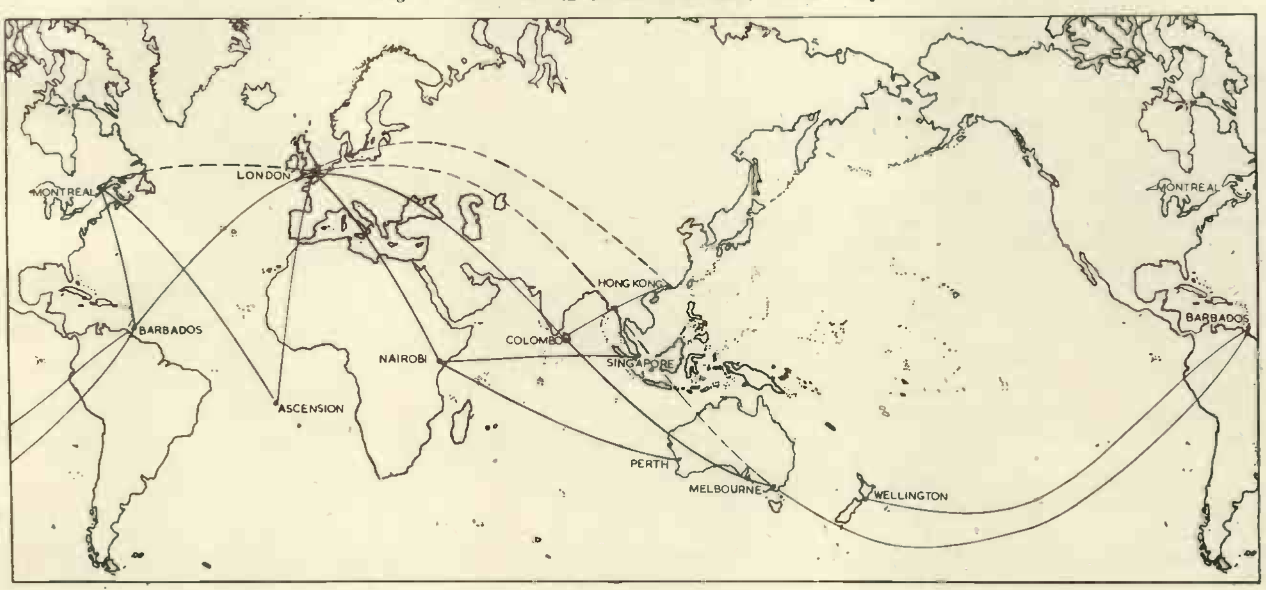
Fig. 6. Predicted M.U.F. and L.U.F. for London-Melbourne (short route)

The charts take no account of the effects of ionospheric disturbances which, by lowering the maximum usable frequency and increasing absorption, further restrict the "pass" band of usable frequencies, so contributing much to the uncertainties of H.F. communication. The transmission path via the ionosphere has, in fact, been likened to a band-pass filter with the disadvantage "that it introduces attenuation, distortion and noise which depend erratically on frequency, time and position, and are not under human control!"

It will be appreciated, therefore, that on this London-Sydney circuit, as indeed on all long-distance radio-telegraph circuits, there are inevitably periods of no communication which can vary considerably in length according to the state of the ionosphere. In the Commonwealth system, with its extensive cable network, temporary interruptions to radio circuits can often be satisfactorily covered by using alternative cable routes, particularly if the failures occur at times when the traffic load is light; but when prolonged interruptions coincide with heavy traffic concentrations steps must be taken to bring the radio circuit back into service through the intermediary of relay stations, located geographically so that the main (unworkable) route is sub-divided into sections for each of which a satisfactory working frequency can be found. (Fig. 7.)

As early as 1930 the London-Montreal and the Montreal-Melbourne beam circuits were thus interconnected to provide a traffic channel between London and Melbourne when direct communications had temporarily failed; but the first overseas point in the Commonwealth equipped specially for radio relaying was Ascension Island in the South Atlantic, in 1939, to improve the overall performance of the London-Montreal circuit. This circuit, passing as it does through an auroral region, is particularly sensitive to geomagnetic disturbances, so that the alternative route via Ascension, substituting two less vulnerable circuits in tandem, is often of considerable value in bridging the gaps experienced in direct working. A similar installation in Singapore for the Australian circuit was interrupted by war, but plans were immediately laid to provide relay facilities at Barbados in the West Indies and Colombo in Ceylon. Both stations came into operation towards the end of the war, while to the same end it was arranged that the Australian terminal of the London circuit could when necessary be transferred from Melbourne across the continent to Perth. Relaying facilities via Nairobi have recently been added to strengthen the position further during the present difficult phase of the sunspot cycle.

Fig. 7. Commonwealth telecommunications, wireless relays



It can be seen by comparing Figs. 3 and 7 that in developing the relay network it was possible to preserve the concept of "cable and wireless." The desirability of so doing lies in the fact that although automatic radio relaying plays a most important part in reducing lost circuit time, it cannot overcome the paralysing effects of the severest ionosphere storms, and on such occasions it can be of great advantage to have the facility for interconnecting workable radio links with appropriate cable sections to reconstitute long-distance circuits.

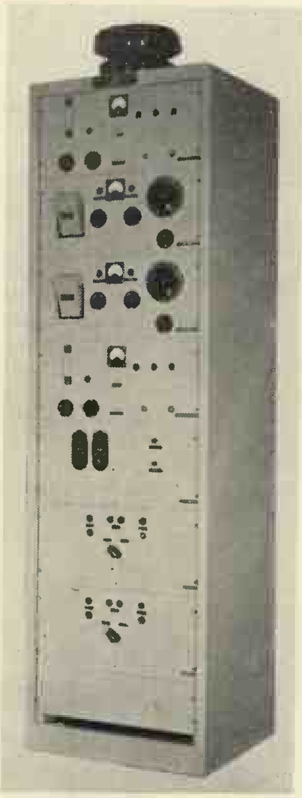


Fig. 8. Electronic regenerator

The actual radio plant at relay points differs in no way from that at terminal stations, but because of the distortion introduced by the transmission medium it is best to "regenerate" the telegraph signals before retransmitting them over a second radio link. Fig. 8 depicts a type of electronic regenerator designed for use with the D.C.C.C. multiplex system, but suitable for regenerating any synchronous telegraph system with an aggregate speed between sixty and three hundred bauds. The principle employed is to explore the centre of each received signal element with a locally generated (resistance-capacitance or crystal-controlled oscillator) 50 microsecond pulse to determine whether it is "mark" or "space," and use the information so obtained to initiate new signals of correct length.

Distortion in high-frequency radio-telegraph circuits is introduced mainly by fading and multipath phenomena, both of which arise from the fact that the electromagnetic waves comprising high-frequency signals can and do travel between transmitter and receiver over a multiplicity of paths of varying lengths and characteristics. With so unstable a medium as the ionosphere, homogeneous neither horizontally nor vertically, even closely adjacent rays, following approximately the same path, arrive at the receiving point with random phase relationship and wave-polarization. Received signal strength dependent on the vector sum of these received rays, can therefore vary between wide limits, fading troughs as deep as thirty to forty decibels being commonly experienced. Fortunately, fading is different in time at points quite close together in space, so that its effect can be substantially reduced by what is termed "space-diversity reception"—selecting the best signals from those received on two (or sometimes three) separate aerial arrays spaced a few wavelengths apart on the same receiving site. Multipath, as its name implies, refers to a condition when signals are received over a number of separate paths, distinguishable by differing times of arrival at the receiving point. The first signals received are those that have had the minimum number of reflexions consistent with the geometry of the circuit; subsequent "echoes," which can produce overlapping components lengthening the signal element by as much as two milliseconds or more, result from the arrival of signal components that have made more but shorter hops.

Returning to the particular case of the telegram from London to Sydney, reception in Australia might be effected at either Melbourne, Perth, or Sydney, according to prevailing route conditions, and whether the circuit was direct from the United Kingdom or via one of the relays already mentioned. Receiving arrangements would be generally similar whichever Australian radio terminal was involved.

The vicissitudes of the ionosphere as a transmission medium have not unnaturally caused unremitting efforts to be directed towards the development of receiving systems capable of maintaining efficient circuit operation in all but the most adverse propagation conditions.

In the fundamental struggle for "signal" against "noise" the gain and directive discrimination of the receiving aerial are naturally of great importance, and most Commonwealth countries retain Franklin beam arrays in their modern form for reception of the particular frequencies for which they are designed. The structurally simple rhombic aerial is often used for reception on other than "beam" frequencies, but Cable and Wireless Ltd. have found their Horizontal Array of Dipoles (H.A.D.) superior in general performance. This array has a forward gain of about 18db compared with a single half-wave aerial, and a front-to-back ratio better than 15db, but its clean polar diagram, free from side-lobes, is the feature which makes it particularly valuable as a receiving aerial. It consists of a series of end-fed dipoles spaced one behind the other directly connected to a central twin-wire feeder and suspended at the required height for the optimum vertical angle of reception. The standard design comprises ten elements in line, and generally two arrays are erected in parallel (Fig. 9).

Aerial to transmission line transformers constructed on Mumetal or Ferroxcube cores are widely used for terminating 600Ω balanced aerial feeders to 75Ω coaxial cable, which on large sites is used to convey the H.F. signal to the receiver building with negligible noise pick-up, or crosstalk from adjacent aerials and feeder runs. When an aerial array covers a wide frequency range and has a sufficiently wide aperture it is often used simultaneously for taking more than one service, and to allow several receivers to be fed from one aerial it is standard practice to terminate the aerial feeder correctly into a valve amplifier in the receiver building, and to provide multiple outputs at the correct impedance for the individual receivers.

The modern high-frequency telegraph receiver is of necessity an elaborate and costly piece of equipment. It is required to select and amplify only the narrow band of frequencies containing the wanted intelligence, rejecting interference from closely adjacent channels the signals in which may often rise to a much greater level than the

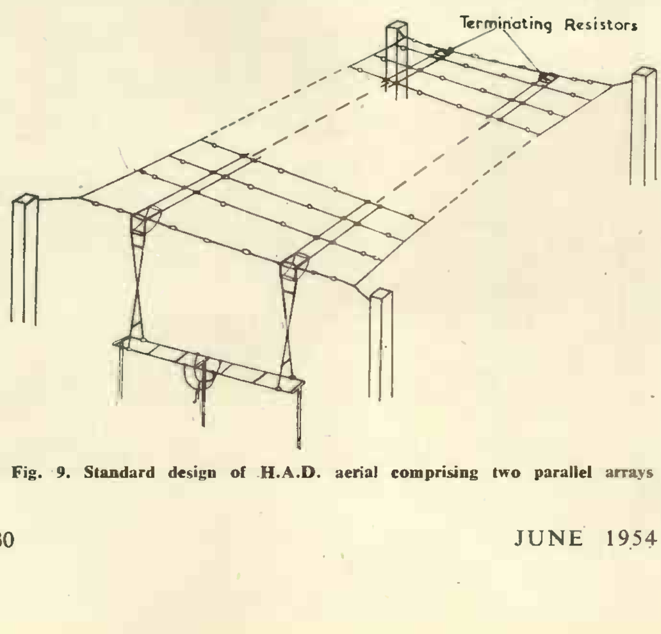


Fig. 9. Standard design of H.A.D. aerial comprising two parallel arrays

wanted signal; it must operate satisfactorily from radio-frequency signals of widely varying levels, and it must maintain such a high degree of stability that essentially unattended operation over long periods is practicable.

The Marconi HR91 is a double-diversity telegraph receiver of the type extensively used on main traffic circuits in the Commonwealth system. It can be continuously tuned over the range 3-27·5Mc/s, but also provides for immediate selection of any one of three pre-tuned spot frequencies—an important feature in facilitating rapid wave-changes. By employing the double superheterodyne design, and using band-pass crystal filters giving 80db protection against unwanted signals 1kc/s from the edge of the pass-band, a very high degree of selectivity is obtained. Automatic frequency correction circuits keep the receiver tuned to within 10c/s of the frequency of the received signal, and the level of the received signal may change by as much as 80db without causing more than a 10db alteration in output level, such rigid automatic gain control being made practicable by the exceptionally large ratio between receiver-overload and recording-threshold levels in this design of receiver.

At the Australian radio receiving station the output of a receiver of design comparable with that just described would be used to key a voice-frequency circuit over a landline into Sydney's Central Telegraph Office. (Where very long landlines are involved the received signals might be electronically regenerated before being retransmitted over the line circuit.) In the Central Telegraph Office, a receiving unit of the synchronous D.C.C.C. system would regenerate the aggregate signal and separate out the two channels of the multiplex which terminate in Direct Printers (Fig. 5). The telegram would thus be received in the form of printed characters on tape, gummed down on to a message form and delivered to the addressee. If it was of average length—containing some twenty to twentyfive text words—about fifteen seconds would elapse between the commencement of its transmission from London as perforated tape and the completion of its reception in printed tape form in Sydney.

With transmit times of this order it is inevitable, particularly in the larger cities of the Commonwealth, that the times occupied in preparing outgoing telegrams for transmission and delivering received telegrams into the hands of their addressees have tended to become the controlling factors in determining the overall speed of service it is possible to give. This situation, it may be remarked, has a close parallel in the field of air transport, where it can also be quicker to fly passengers hundreds of miles between terminal airports than to convey them by road to and from those airports! Phonogram, telex and high-speed fascimile systems have all been developed to improve collection and delivery times, and in the United Kingdom the position has been materially strengthened with the conversion of the inland service to an automatic switching system whereby the Overseas Telegraph Office in London can dial and transmit by teleprinter to every major telegraph office in the country.

Looking towards the future, there seems little doubt that the rapid and continuing growth of air transport, and the introduction of high-speed commercial aircraft on regular scheduled flights between the continents, must result in a need for more and faster international telegraph services, with particular emphasis on subscriber-to-subscriber operation.

The difficulty of accommodating additional high frequency circuit requirements in an already overcrowded part of the spectrum is the basic problem facing radio telecommunication engineers today, and most of present day research and development work is, to a greater or less extent, directed towards its solution.

In the Commonwealth system, to achieve the most effective use of available high-frequency allocations it can be anticipated that increasing use will be made of frequency-division channelling by modulating an independent side-band transmitter with up to three F.M.,V.F. (frequency-modulated voice-frequency) tones to produce the same number of frequency-shift telegraph channels, spaced in frequency by no more than one kilocycle per second. Each channel, capable of further sub-division by time-division methods, will normally be received on a separate frequency-shift receiver, and individual channels may be used to serve different destinations provided the distances and bearings of the receiving points are such that similar route conditions prevail.

A less elaborate channelling system known as Frequency-shift Diplex promises to come into extensive use on more lightly loaded circuits. (See Page 268.)

Time-division channelling, which also plays an important part in obtaining the most efficient utilization of available circuit capacity, can be expected to grow rapidly with the demand for subscriber-to-subscriber, or as it is sometimes called "leased channel" operation. Systems designed specifically for 7 unit error-detecting teleprinter codes, and incorporating error-correcting facilities, are already in an advanced stage of development in the Commonwealth while the D.C.C.C. system, as already mentioned, has been adapted to allow one channel of 7 unit to be combined for transmission with a channel of cable code, to preserve the required flexibility in the usage of radio and cables.

These measures, together with the continued development of radio-frequency transmitters and receivers of improved frequency stability, of aerial arrays to take account of the varying azimuthal and zenithal wave arrival angles encountered in practice, and of additional relay stations to increase alternative routing facilities, should help materially to reduce the gap between present practice and ideal performance.

Many difficult problems, however, remain to be solved. There is, for example, much more to be learned about the fundamental characteristics of ionospheric storms and their causes before dislocation of high-frequency communications can be avoided by giving the operating agencies reliable storm warnings in time for alternative measures to be put into effect. And finally, as many listeners to medium frequency broadcasting in this country will appreciate, interference from other radio transmissions, some of which are not particularly amenable to international discipline, can seriously degrade, or in the worst cases completely interrupt, the best engineered of high-frequency radio circuits.

Nevertheless, the advent of repeatered submarine coaxial cables promises to mark yet another revolutionary step forward in long distance communications, and the Commonwealth with its integrated cable and H.F. radio network, should be as well placed in 1954 as it was in 1924 to derive the fullest advantages from developments in either sphere.

Acknowledgment

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REFERENCES

VYVYAN, R. N. Wireless Over Thirty Years (Routledge 1933).
LADNER, A. W., STONER, C. R. Short-Wave Wireless Communication (Chapman and Hall).
SMALE, J. A. Radio Section : Chairman's Address. *Proc., Instn. Elect. Engrs. 101*, Pt. III, 1 (1954).
WOOD, K. L. Empire Telegraph Communications. *J. Instn. Elect. Engrs. 84* (1939).
Characteristics of the Ionosphere. Radio Research Special Report No. 23 (H.M. Stationery Office, 1953).
TREMELLEN, K. W., COX, J. W. The Influence of Wave Propagation on the Planning of Short-Wave Communication. *J. Instn. Elect. Engrs. 94*, Pt. IIIA (1947).
SMALE, J. A. Some Developments in Commercial Point-to-Point Radiotelegraphy. *J. Instn. Elect. Engrs. 94*, Pt. IIIA (1947).
MUMFORD, A. H. Long-Distance Point-to-Point Communication. *J. Instn. Elect. Engrs. 94*, Pt. IIIA 1947).

H.F. COMMUNICATION SYSTEMS

A Review of Current Practice

By A. W. Cole*, A.M.I.E.E.

LONG distance point-to-point radio communication is now nearly 50 years old, and until about 1925 was conducted entirely on V.L.F. (long wave) channels which have a relatively low traffic handling capacity due to the high noise levels and the inefficiency of the transmitter radiator system.

After the first World War very considerable effort was applied to using H.F. for long distance operation. This work was carried on in many parts of the world, both by amateurs and professionals, but it is generally agreed that the first successful commercial application was made in this country by the Marconi Company when it introduced its famous Beam System, which came into operation in 1926.

Using this system, high speed telegraph circuits were set up in the Commonwealth and subsequently extended to other countries. Parallel development in other countries was accelerated and within a very short time large numbers of long distance high speed telegraph circuits were in use all over the world. This development had an appreciable effect on the existing submarine cable companies, but eventually there was a good deal of collaboration between the two interests and the world telegraph system is now largely co-ordinated. Apart from other things, the existence of these large radio systems revolutionized the telegraphing habits, particularly of the business communities.

Very shortly after the inauguration of these high speed telegraph systems, the same circuits were used for telephony, using double sideband transmissions. Thus, soon after 1930, H.F. systems were carrying a major part of the inter-continental telegraph and telephone communication.

Apart from these common carrier systems for public use, similar communication systems were brought into use by the Armed Forces of various countries, for the first time enabling them to be partially independent of the various submarine cable routes and providing a degree of flexibility which had hitherto been impossible. While the general development of the H.F. communication systems has been governed by the civil requirements, the Services have contributed extensively to the available knowledge and have influenced the main lines of development.

During the last war, the far flung nature of military and other operations called for a further vast increase in the available civil and military communications capacity and effort was devoted not only to improving the efficiency of existing and new circuits, but also to introducing printing telegraph operation on a large scale.

While amplitude modulation, commonly known as on-off modulation, is still largely used for telegraph operation, frequency shift modulation is coming into greater use. Single sideband operation is now almost universal for important telephone systems.

At the present time the more important international circuits operate with time division, printing telegraph multiplex systems for telegraphy and independent sideband systems for telephony, in some cases providing two telephone channels on each sideband. Over the years there have also been substantial developments towards obtaining privacy on the telephone channels.

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In addition to the normal point-to-point application there are various world networks operated for news-cast services either employing Hellschreiber or 5-unit printers and in some cases morse transmission.

Considerable use is also made of the point-to-point services for carrying broadcast programmes from one part of the world to another.

The extensive development of the operational requirements has led to many detail improvements on the equipment and also on the arrangement of the plant on radio stations, particularly with a view to reducing personnel requirements and obtaining greater reliability. The position now reached is that there is a tendency towards standardization of technique and ideas and a strong urge towards the improvement of performance on an international basis.

Some Current Problems

The full scope of international H.F. communication may not be fully realized. There are thousands of channels in use, the most heavily loaded ones being used by public carriers, often operating both telegraphy and telephony on a multi-channel basis.

Unfortunately the world system is not based on a logical plan, but has grown up on the basis of a very large number of often unrelated circuits operating between individual countries. But for national policy and considerations of national security the number of channels in use could be drastically reduced by routing telephone and telegraph traffic into the main trunk systems of the world rather than operating a large number of lightly loaded point-to-point circuits.

Most countries of the world operate an overseas radio communications service and even quite small countries may operate a number of long distance services giving direct access to most parts of the world.

While main trunk services are fully loaded and make economical use of the frequency spectrum, other services are too lightly loaded or technically insufficient and are often occupying bandwidth in a manner which cannot be considered as entirely economical, having particular regard to the shortage of channels.

However, the issue is largely a political one and in the foreseeable future it does not appear that much can be done to reduce the number of channels in operation. On the contrary, the number of channels is likely to increase.

Quite apart, therefore, from the need for technical improvements in the search for better quality systems, the heavy loading of the available H.F. band makes it very necessary to study all possibilities of avoiding inter-channel interference. The main approaches to this problem are to increase frequency stability and to reduce the transmitted bandwidth to the minimum required for the particular service involved.

Reduction of bandwidth is not the only problem which needs to receive attention. Many of the directional aerials used, particularly for transmission, are of such a design that the horizontal polar diagram has major side lobes which transmit a very considerable percentage of the energy in unwanted directions. For receiving arrays this problem is less serious in that end-fire arrays such as the RCA Fishbone or the Cable & Wireless H.A.D. (Horizontal Array of Dipoles) do give very much greater protection in this respect. For transmission, however, the rhombic aerial is in common use and without elaborate combinations of arrays and restriction of bandwidth it has so far proved difficult to reduce side lobes to reasonable proportions for transmission purposes.

Control of Bandwidth

The position is far from satisfactory, many transmitters in current use barely conforming to the Atlantic City requirements for frequency stability and many transmitting very considerable energy outside the strictly required bandwidth.

The definition of the strictly required bandwidth is obviously one of some difficulty and has engaged the attention of successive international conferences. Slowly, however, the required performance of transmitters is being defined and it may be expected that at the next I.T.U. Conference (which should be held in 1958) regulations may be formulated governing at least some aspects of this problem.

In the meantime the design of transmitters is receiving special attention in all parts of the world and it is now generally accepted that for telegraphy it is preferable to use frequency shift (F1) transmission in that, being a constant amplitude system with low power modulation it is possible to introduce bandwidth restricting elements without great difficulty. If amplitude modulation (A1) is still to be used then a radical improvement can be made only if linear transmitters are utilized. As such transmitters are coming into current use for single sideband telephony it is convenient to use the same type of equipment for A1 telegraphy. With linear transmitters the bandwidth can be determined in the low power modulating stage of the transmitter and is then only degraded in terms of the non-linearity of the transmitter itself. Despite the non-linearity which occurs in the transmitter the overall effect is satisfactory and may well meet any international regulations of the future.

Some interesting measurements have been made of the bandwidth of a modern linear transmitter with A1 modulation. These measurements were carried out using an analysing filter which permitted the various components in the transmitted spectrum to be separated and measured. The transmitter was modulated with telegraph reversals at 240 bauds. Measurements were possible at levels of −50db or more referred to the carrier amplitude, and the results are indicated in Fig. 1.

The results show that at 240 bauds the transmitter substantially meets the C.C.I.R. 1948 recommendation and with a suitable design of low-pass filter inserted in the input to the low-power modulator the recommended performance can be obtained.

In this case the original telegraph waveform was such that the higher order harmonics were eliminated before application to the modulator and broadly the telegraph signal contained up to the fifth harmonic of the fundamental keying frequency. With such a condition the bandwidth on frequency shift is somewhat greater than with A1 modulation but, on the other hand, it is not necessary to have a linear transmitter and the required bandwidth condition is more easily maintained. If the transmitter is to be used for telegraph only there is some considerable advantage in using a class-C condition; in a typical case the continuous rating of the transmitter may be 75 per cent higher for class-C operation than for the linear condition using the same valves and circuit constants.

The position on telephony is somewhat more satisfactory in that single sideband operation is now being utilized almost exclusively and the determination of bandwidth is again mainly a function of the non-linear factors in the transmitter amplifier. With the increasing need for multi-channel operation it fortuitously happens that there has been a need for linear amplifiers having less distortion and this in itself will result in the products thrown outside the strict modulation band being reduced to an absolute minimum.

It will be seen that the major problem is, therefore, that of A1 telegraphy and that if it does not prove possible to replace existing class-C transmitters by linear transmitters for this purpose, then the adoption of F1 operation will become much more necessary and rapid than it has been in the past.

This delay in the adoption of what appears to be a much better system has been due to a number of factors. First, when frequency shift operation was first used by American interests during the war, the claims made were such that they could not be substantiated on traffic operation. The change to frequency shift did not always provide an immediate remedy in the case of a circuit which was

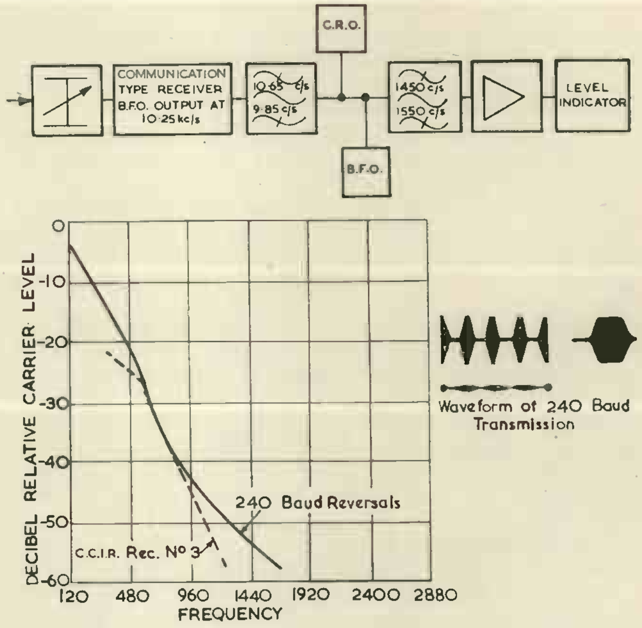

Fig. 1. Bandwidth measurements, 240 baud transmission

operating poorly, and under certain radio conditions does not necessarily give the signal-to-noise improvement or reduction of distortion which is anticipated. The study of the transmission phenomena associated with frequency modulation for long distance telegraphy has occupied several years and it is only gradually that the right constants for this system are being evolved and really satisfactory operation obtained.

It is felt by the author that there has been a tendency to place far too much emphasis on the virtues of such improved systems as frequency shift working without paying proper attention to basically good engineering practice on the circuit involved. It is only too true that many high frequency point-to-point circuits have been brought into operation without proper investigation into the power requirements, sites, aerial systems and frequencies. Under these conditions many circuits operate in a relatively inefficient manner over a long period and it is often difficult to analyse all the factors involved and to bring about a more satisfactory standard of working.

Problems affecting bandwidth on receiving stations are less difficult and in general it can be said that technical developments have reached a satisfactory standard and at present little further improvements are called for in the specifications for the better types of receivers. The design of crystal lattice filters and *LC* filters of various types has

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reached such a stage that almost any normal requirements in ultimate bandwidth of the receiver can be met. Such problems as are left are mainly connected with the inevitable wide acceptance band of R.F. amplifiers and the first frequency changers of receivers. Considerable cross modulation can take place in these early stages of the receivers and as it is not an easy matter to provide adequate selectivity prior to such amplifiers and non-linear elements, it has become the practice to design the amplifier to cater for a wide range of input voltages. Thus, in a current receiver it is possible to carry an adjacent channel interfering signal 60db above that of the wanted signal without marked cross modulation effects.

Although it is a relatively easy matter to design ultimate filters in the receiver which have any required bandwidth, some inconvenience may be caused by the phase delay characteristics of such filters. Thus, in experimental frequency shift systems using a small shift in a narrow band, very considerable distortion can be caused through unequal phase delay near the cut-off frequency of the filter; this is a matter which is receiving attention and there is no reason why it should not be ultimately solved.

Trends in Telegraph Modulation

The increasing use of frequency shift modulation has already received comment. When this system was first brought into normal use a shift of 850c/s was commonly used. This shift was not introduced on any true scientific basis, but came about largely because the original designer had available standard filters which suited this shift. Subsequently it has become common to use a 500c/s shift for most systems.

Recent work on frequency shift systems has tended to show that smaller shifts and narrower bands would be more satisfactory and a number of experimental narrow band systems are in use. In a preferred system the overall bandwidth employed, taken at points 3db down, is 500c/s and the frequency shift is of the order of 200c/s. Such a system will accommodate a high speed time division multiplex system and can be used for most types of telegraph transmission.

For single channel start-stop or synchronous systems a bandwidth of 300c/s is envisaged with a shift of 100c/s.

A basic problem on telegraph systems is that of dividing the high speed capacity of the system into slower speed channels in order to give more efficient operation and to provide more flexibility. On land line systems it is conventional to provide this channelling by means of frequency division, but so far on radio systems time division has found more favour.

Time division has certain limits in that the existence of multi-path effects on the long distance routes sets a limit to the maximum keying speed and the capacity of the system. In most cases this maximum (which may be generally accepted as 160 bauds) is sufficient to permit of the required traffic being carried without difficulty and there are several successful systems which have been in use for many years.

One of the minor drawbacks of time division systems is that they are of necessity synchronous and it is sometimes difficult to link the channels to other telegraph systems which may be running at different speeds or operating under different conditions. For this reason there is also scope in the international radio communication field for frequency division channelling systems.

Some effort has been made to obtain this form of channelling by using conventional line V.F. telegraph equipment on a 2-tone basis, i.e. using one tone for mark and a second for space in order to achieve a polar signalling effect. This arrangement has proved reasonably satisfactory on stable and mainly moderate length circuits, but for the more difficult and longer distance systems it has proved to be only partially successful.

Telecommunications engineers have, therefore, given considerable attention to the possible use of frequency shift V.F. telegraph channels as an alternative, and the experimental results have been attended with some success. A typical system provides for the transmission of three frequency shift V.F. telegraph channels within an overall 3 000c/s bandwidth (i.e. one "unit" of an independent sideband transmission). The liability to error has been proved to be very much less than that with 2-tone systems and there is no question that systems of this type will come into regular use in future.

For the receiving terminals of such systems it was originally the practice to use an independent sideband receiver using diversity and to combine the channels after demodulation. It has been found in practice, however, that improved results can be obtained by using separate telegraph diversity receivers for each channel. Not only does this give better overall results in that each receiver is set up to cope ideally with one channel, but the arrangement gives greater operational flexibility. This is leading to the practice of obtaining transmitter economy by operating a linear transmitter to a number of destinations on roughly the same route by means of this type of channelling; each distant terminal station receiving the channel it requires on a normal diversity telegraph receiver.

In some cases there is a call for a less elaborate channelling system and in this case it is possible to use frequency shift diplex. This arrangement uses a normal frequency shift transmitter which is capable of being modulated on to one of four discrete frequencies. With these conditions it is possible to transmit two simultaneous telegraph channels using four possible combinations which may be as set out in the following table:

FREQUENCY TRANSMITTED	CHANNEL A	CHANNEL B
f_1	Space	Mark
f_2	Space	Space
f_3	Mark	Space
f_4	Mark	Mark

The frequency shift diplex system has the advantage that it requires relatively small changes on the transmitter and receiver and, in effect, doubles the capacity of the circuit with little expense. There is, of course, a degradation of performance due to the increased bandwidth and also because the random signalling on the two channels may give rise to transient conditions, the elimination of which causes occasional delay in telegraph signalling.

Transmitting Station Plant

The conventional radio transmitters of the past have usually been self-contained and mainly designed to perform a single function. The most common form of medium and high power H.F. transmitter has been an equipment using class-C amplification with a self-contained drive system giving a choice of several crystal frequencies and probably with an emergency *LC* oscillator. The telegraph modulation has been carried out at low or medium power and in order to avoid undue bandspread due to keying transients, time-constants have been inserted in the keying circuits.

This solution has never been entirely satisfactory because the limiting action of the class-C amplifiers does in fact subsequently remove a good deal of the "shaping" introduced by the time-constant arrangement. Thus, under conditions of varying supply voltage and tuning adjustments in the transmitter and the amount of drive applied to the various stages, marked variations in bandwidth could take place, but nevertheless with careful maintenance and attention and with efficient technical operating staff, it has been possible to operate such transmitters in a fairly satisfactory manner. Unfortunately, the majority of such transmitters are not necessarily operated under ideal conditions and considerable interference is caused by excessive bandwidth of the telegraph transmissions.

Additionally, some transmitters as have been manufactured to date do not normally meet the requirements of frequency stability. Under the Atlantic City Regulations, transmitters are required to have a stability of 30 parts in 10^6 and numbers of the transmitters in use can only just meet this requirement.

There has been a progressive introduction of F1 operation and with class-C transmitters this has resulted in a marked reduction in the interfering effects due to telegraph keying. It might even be said that one of the main advantages of using F1 is that the bandwidth can be more easily determined and controlled and this benefit is equally as important as any signal-to-noise improvement at a receiver.

With the development of various systems it has become necessary to consider more flexible transmitting arrangements. A modern transmitting station may be called upon to handle any of the following types of service:

(1) S.S.B. telephony.
(2) S.S.B. transmission with multiple telegraph channels.
(3) Frequency shift telegraphy, F1.
(4) Frequency shift diplex telegraphy.
(5) On-off telegraphy, A1 or A2.
(6) Double sideband telephony.

With the older types of plant it has normally been necessary to have separate telegraph and telephone transmitters, particularly where single sideband operation is required. Where many mixed services are operated this is a great disadvantage and the modern trend is to produce a type of transmitter which will cater for all systems when a suitable low power modulator is applied to the input.

The overall flexibility of systems is also concerned with utilization of aerials. In some large stations quite comprehensive feeder and aerial commutation schemes have been evolved, most of the fully flexible schemes being based on using coaxial feeders. This does bring in limitations in that in matching the unbalanced coaxial feeder to balanced aerial systems it is usually necessary to have a frequency conscious network. This has led to complications in switching tuned circuit elements in the field by remote control or with other forms of remote tuning mechanisms. Thus, considerable attention has been paid to open wire switching systems which merely need a commutating device for direct connexion of the transmitter feeder to the required aerial system.

To meet the modern requirements, system design engineers have, therefore, separated the various parts of the complete transmitting system in such a manner that full flexibility can be easily obtained. The various parts of the system can be tabulated as follows:

(1) The primary frequency drive system.
(2) The low power modulating system.
(3) An amplifier capable of delivering the output of the low power modulator to the feeder at an appropriate level.
(4) A feeder commutating arrangement.

The drive system is satisfied by providing a bank of single frequency crystal drive units of a compact type, one unit being provided for each radiated frequency on a station. As the standard output frequency of the low power modulating system is 3·1Mc/s the primary crystal drive frequencies are suitably offset. To simplify the driving arrangements, all the crystal frequencies fall within the range 2-8Mc/s.

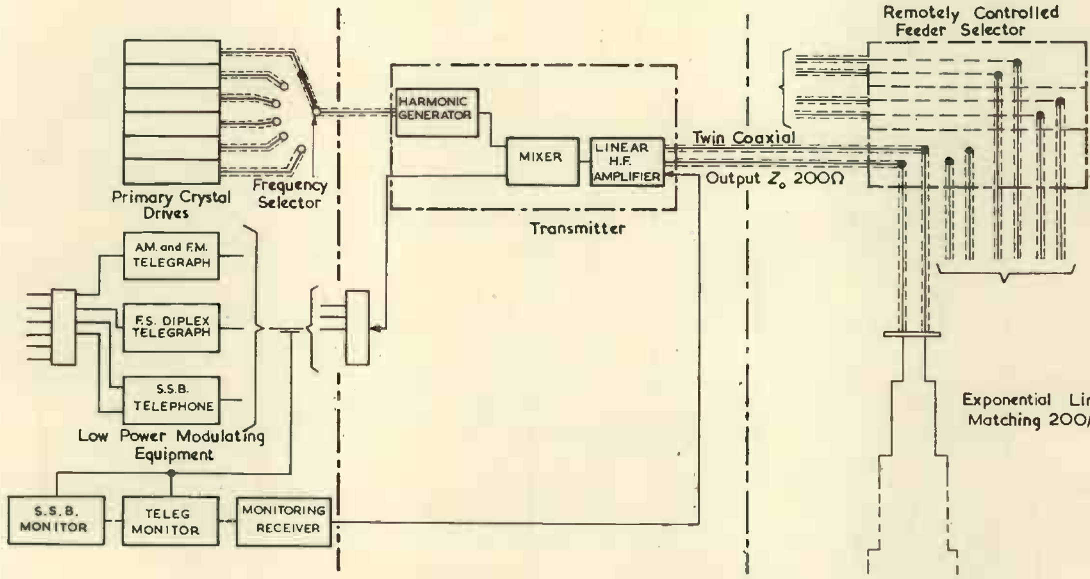


Fig. 2. Arrangement of units in a typical H.F. transmitting station

The standard output level of each drive unit is 100 milliwatts into a 75 ohm coaxial feeder. The frequency stability is better than 5 parts in 10^6.

The low power modulating system can utilize any of the following:

(1) A frequency shift and on-off keying unit which provides for telegraph speeds up to 400 bauds and frequency shifts up to 1 200c/s.
(2) A frequency shift diplex sending unit which provides two simultaneous telegraph channels on the basis of a 4-point frequency shift or normal frequency keying or on-off keying.
(3) An S.S.B. drive rack of the conventional type providing two independent sidebands each with a bandwidth of 6 000c/s.

All these units deliver a modulated signal at about 100 milliwatts into a 75 ohm feeder and are fed directly to the transmitter which is nothing more than a linear amplifier. This linear amplifier has two inputs, one for the primary drive frequency and one for the low power modulated intelligence. The primary drive frequency is fed into a harmonic generator and when multiplied to the appropriate radio frequency it is mixed in a simple mixer stage with the low power modulator signals.

The remainder of the transmitter is a class-B amplifier delivering x kilowatts into the feeder system.

In a typical range the transmitters may have an output of $2\frac{1}{2}$ kilowatts, 10 kilowatts or 30 kilowatts.

Transmitters can be tuned automatically from remote control positions so that one of up to six frequencies can be transmitted.

For feeder commutation several types have been constructed using 600 ohm open wire feeders as the basis. A typical example is the Miller Switch which can be arranged to be fully flexible up to a limited number of transmitters and receivers. A typical switch provides for 20 transmitters and will connect any of these units to any one of 40 aerial feeders.

The open wire switch, while being robust and flexible, has disadvantages in that if mechanized it becomes costly, and also occupies a large volume of space.

Coaxial switches using the Swiss commutator principle have been in use for many years, but, as already mentioned, have the disability that ultimately the overall system becomes frequency conscious. When such switches were originally designed they were used with curtain arrays having a very narrow bandwidth and with the more general adoption of wideband aerials such as the rhombic, their use has become limited.

To overcome this difficulty a most promising development is now taking place, and that is the use of twin coaxial feeders for the commutating system. Such a system, having an impedance of about 200 ohms, can be connected to a 600 ohm open wire feeder through a wideband exponential line and thus the mechanical advantages of the coaxial type of switch are obtained in a balanced system. Nevertheless, this type of cross connexion switch can never be as conveniently flexible as are rotary switches of the Miller type, and it is usual to operate them on a zonal or group basis; each transmitter normally having access to a limited number of aerial feeders with additional access being provided by means of manual connexions.

In some cases the operation of the switch may be automatically linked to the control circuits of a transmitter so that previously planned programmes and frequencies can be set up complete with the required aerial system.

The unit arrangement of an H.F. transmitting station is shown in Fig. 2.

Receiving Plant

The arrangement of medium and large size H.F. receiving stations has generally been stabilized for some years. On most stations the balanced twin wire feeders are terminated by means of dust core transformers into a 75 ohm coaxial cable. These transformers may be mounted in the field adjacent to the aerial or on frameworks near the main receiving building.

The coaxial feeders are then taken to a main distribution switchboard where they can be connected directly to receivers, but are usually fed to amplifiers having multiple outputs, so that a number of receivers can be connected simultaneously to one receiving feeder cable.

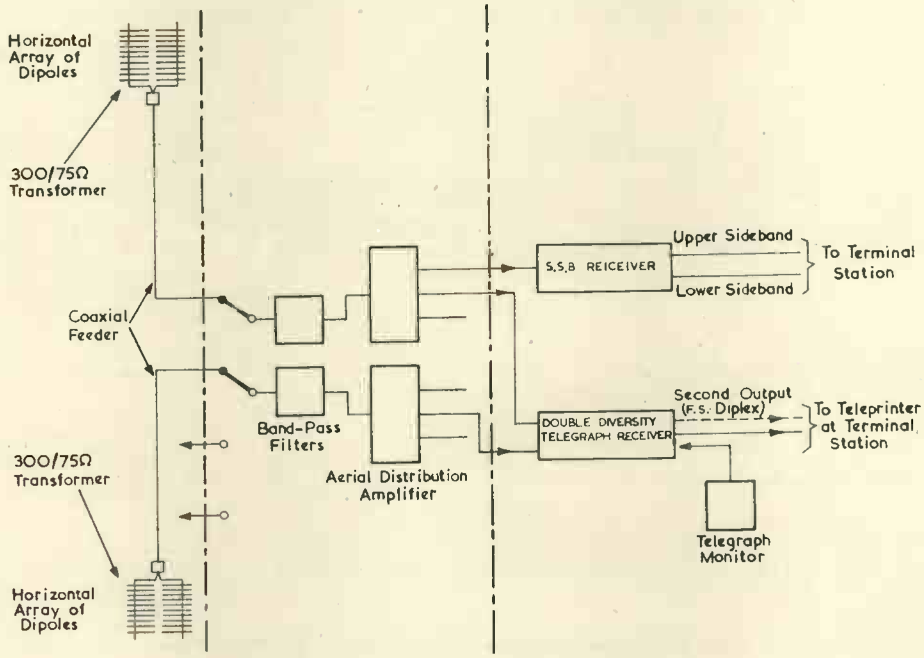


Fig. 3. Typical receiving station unit arrangement

It is the modern practice to insert a band-pass filter in the input to the distribution amplifier, this filter having not more than one octave bandwidth and normally having a similar bandwidth to that of the aerial system. The insertion of this filter minimizes the production of spurious outputs in the distribution amplifier.

The distribution amplifier normally uses cathode-follower outputs which are terminated into coaxial cables for distribution to the receivers.

For the trunk telegraph systems, diversity receivers are used which have a very high performance and which are provided with elaborate monitoring facilities. A typical receiving station unit arrangement is shown in Fig. 3.

For single sideband telephone reception, diversity is not normally used, as in general no advantage can be gained. This is partly because of the relatively wide bandwidth of the system and the fact that any path selecting device in a diversity receiver is not able to differentiate between different types of selective fading within an audio frequency band.

A High Power Communication Transmitter

W. J. Morcom*

This article describes a new single sideband transmitter for world-wide service. Its design has been based on the requirement of (a) remote control; (b) four telephone channel operation. Although this article only describes the transmitter rated for 30kW peak envelope power, a whole series of transmitters, generally similar in circuit techniques, have been, or are being, produced of powers of 2½kW, 6kW, and 10kW peak envelope power.

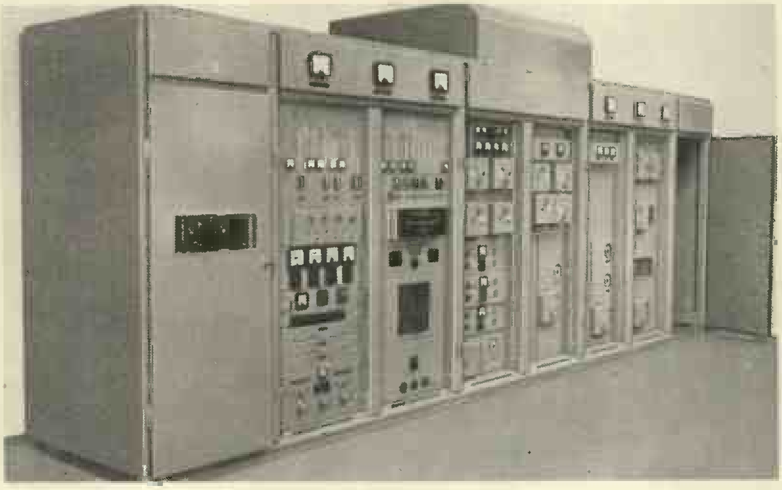
FROM an economic viewpoint it must be possible to transmit the maximum number of messages in any 24 hours between two points. It follows that maximum power should be used to cover as long a period as possible on any one frequency, and that frequency change must be rapid when conditions on that frequency become impossible. From a power aspect the advantages of S.S.B. or I.S.B. (independent sideband) systems are well known in that the bulk of the output power of the transmitter is radiated in the form of intelligence, whereas in a D.S.B. system the power conveying intelligence is only 1/6th of the total radiated output. The advantages of I.S.B. are further increased by the fact that with good linear amplifiers four speech channels can be used on one transmitter within a bandwidth of 12kc/s, without undue cross-talk. Also the coincidence of peaks of modulation between two or more channels in a four-channel system is not a frequent occurrence, so that the level of each channel can be approximately the same as that where only one channel is used, without overloading the transmitter. This has been confirmed by field trials. This system is not limited to speech channels, and multi-channel telegraph working can be used without any alteration at the transmitter. Thus the choice of service is in the hands of the operators at the radio telephone terminal. In the case of c.w. telegraphy, the linear amplifiers enable the low level signal curbing to be faithfully reproduced on the transmitter output, thus avoiding adjacent channel interference.

Remote control of frequency change is carried out by the use of individual motors and associated control mechanism units, mounted on the front panels and each driving an individual frequency changing control. This provides automatic selection of six preset spot frequencies or manual tuning anywhere in the frequency band. Because of the high power of the transmitter and the large components to be operated, the wavechange time is of the order of 1½ minutes maximum.

To limit the number of control spindles to be operated, ganged inductance and capacitance circuits are used. In the higher power stages the whole frequency band of 4-27·5Mc/s is covered by one control shaft. A new design of variable capacitor using sulphur hexafluride as dielectric has been developed for this purpose.

Control circuit design and reliability of performance are considerably improved by the use of grid controlled, mercury pool Ignatron tubes in the rectifier.

So that the greatest flexibility of use may be provided the drive and the single sideband generating equipment have been divorced from the transmitter proper, which is in reality only a mixer plus linear amplifier. (See Fig. 1). This has the advantage that alternate services of S.S.B., F.S.K., C.W. or D.S.B. telephony can be provided by a simple plugging in operation from suitable external equipment. Where multiple transmitters and multiple drives are used this inter-changeability contributes enormously to the flexibility of the station.



Front view of the type HS.51 transmitter with the doors removed.

General Performance

This transmitter operates in the band 4-27·5Mc/s. Both sidebands are used so that up to four separate speech channels may be operated. Attenuated carrier is also radiated. Alternatively telegraph tone keyed channels may be used.

The peak envelope power of the transmitter is 30kW and the design has been done to meet Services requirement as regards preferred components and valves, and for tropical operation to Specification RCS.1000.

Control facilities permit local or remote operation on six preset spot frequencies, or local control, manually, on any frequency in the band.

Feeder impedances may be 600Ω twin, 200Ω twin or 75Ω coaxial with a standing wave ratio of 2/1, i.e. a range of 100 to 1 200Ω in the twin wire condition.

Recent experience has shown that when the transmitter is loaded to maximum power by two equal tones the intermodulation products should be less than −36db in relation to the amplitude of the individual tones. The use of a spectrum analyser showed that all intermodulation products so complied.

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The noise level was better than −60db relative to peak envelope power on I.S.B.

Circuit Description

HARMONIC GENERATOR AND MIXER STAGES

The transmitter specification calls for 6 spot frequency outputs in the band 4-27·5Mc/s with input signals of 3·1Mc/s (¼ watt I.S.B.) and 3·4-7·0Mc/s (1/10 watt). Since a very high performance with regard to spurious frequencies was required it was decided from the outset to use six separate mixer units, each of which could be switched bodily and each be tuned to give optimum performance, rather than proceed with a ganged mixer which could only give a compromise performance over a wide tuning band.

In general two types of spurious emission will be generated in a mixer of the type shown in Fig. 1.

(a) Frequencies which are far removed from the wanted radiated frequency and which can be removed to a given degree by adequate selectivity depending on economic and space considerations.

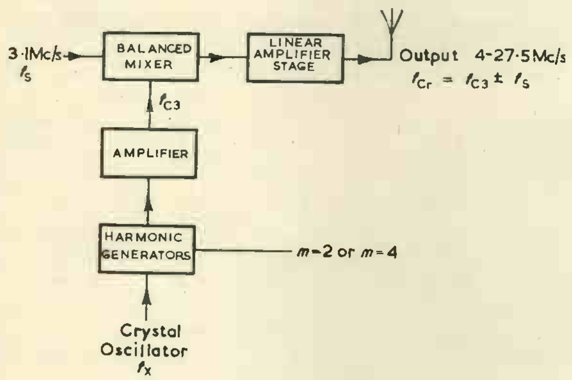


Fig. 1. Arrangement of transmitter stages

(b) Frequencies which are coincident with or in audio range of the radiated frequency. These cannot be removed by stage selectivity and must be guarded against by arranging that they fall outside the wanted band as far as possible. Some coincident points are inevitable, but the amplitude of these can be restricted by using a very small input signal at 3·1Mc/s, ensuring that both oscillators have a pure sine waveform and that intermodulation due to non-linearity of the mixer stage itself is reduced to a minimum.

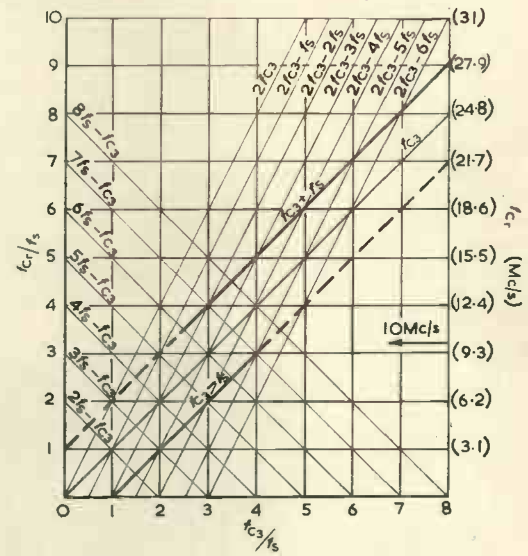
PREDICTION OF COINCIDENCE POINTS

These are worked out by constructing a chart of the type shown. For the sake of clarity the basic chart has been split up into three sections, of which only one section is reproduced here (Fig. 2). The ordinate is scaled in terms of f_{cr}/f_s (and also in terms of radiated frequency f_{cr}) while the abscissa is f_{c3}/f_s. There are three lines on the chart at angles of 45°. Two of these lines represent the desired signal and are marked $f_{c3} - f_s$ (= radiated frequency below 10Mc/s) and $f_{c3} + f_s$ (= radiated frequency above 10Mc/s) respectively, while the third line is mixer input frequency f_{c3}.

Fig. 2 includes all terms in which n in the expression $nf_{c3} + pf_s$ has only integral values, the remaining portion of the charts would include those terms in which n is fractional and $m = 2$ and those terms in which n is fractional and $m = 4$.

GANGING OF CONTROLS

It is usual to employ either a variable capacitor or inductor as the tuning element in the amplifier stages. To cover the normal frequency band of 4-27·5Mc/s, a number of fixed inductors or capacitors must be employed. By ganging a suitable variable capacitor and a variable inductor together, the whole frequency band of 4-27·5Mc/s can be covered on one tuning control, thus avoiding range switching or coil changing. Neutralizing R.F. amplifiers is another obstacle to a rapid frequency changing so that neutralizing must be constant over the frequency band—a difficult achievement on the multiplicity of amplifiers—or neutralizing must be avoided, such as by the use of tetrode stages or grounded grid stages.



LIST OF SYMBOLS

f_s Independent sideband signal fed to mixer input from I.S.B. drive unit

f_{c3} Oscillator input signal to the mixer stage

n Any multiple of f_{c3}

p Any multiple of f_s

f_{cr} Mixer unit output frequency

$$\begin{cases} f_{cr} = f_{c3} + f_s \text{ for } f_{cr} \geqslant 10\text{Mc/s} \\ f_{cr} = f_{c3} - f_s \text{ for } f_{cr} \leqslant 10\text{Mc/s} \end{cases}$$

$nf_{c3} \pm pf_s$ general product in mixer output as a result of mixing the two input frequencies f_s and f_{c3}

f_x Crystal frequency from which f_{c3} is derived

m Multiplication employed in the H.G. producing f_{c3} ($f_{c3} = mf_x$)

(In the design in question m = 1, 2 or 4)

Fig. 2. Chart for prediction of coincidence points

The figures in brackets on the right-hand ordinate give the radiated frequency (f_{cr}) in Mc/s.

LINEAR AMPLIFIERS

One of the main causes of non-linearity in R.F. amplifiers is the change of input impedance produced by grid current, so it is advisable to limit the number of stages where grid current is flowing to a minimum. One satisfactory solution to this problem is to use a high power gain tetrode, in which the grid never swings positive with respect to the cathode, so that it can be driven by a voltage amplifier. In the succeeding power amplifiers, where grid current is practically unavoidable, various methods have been employed to reduce its effect on linearity. Early transmitters used damping on the grid circuit, but to be effective the load produced by the damping must be considerably greater than that produced by grid current. This makes this system very wasteful. Another method is to employ an adjustable quarter-wave network between the anode of the power tetrode and the grid of the succeeding stage. The constant current characteristics of the tetrode is converted by the quarter-wave network to constant voltage characteristics at the grid of the succeeding stage, and the effect of grid current on linearity is reduced to negligible proportions. This is a very effective system, but the disadvantages are the setting up of the quarter-wave network for rapid frequency change, containing as it does three variable elements, and the fact that the succeeding amplifier must be neutralized. A third method of reducing the effect of grid current on linearity is to use grounded grid amplifiers, where the grid cathode load due to the anode current is considerably greater than that due to grid current. Also the grounded grid amplifier does not have to be neutralized. From these considerations it appears that the most suitable arrangement for linear power amplifiers is a power tetrode which does not run into grid current, followed by grounded grid power amplifiers.

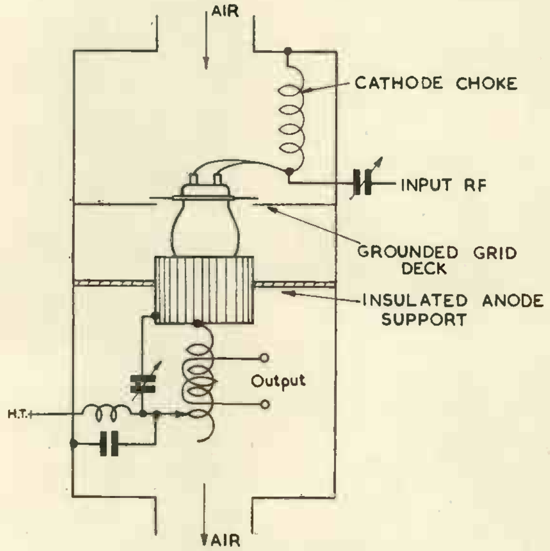


Fig. 3. The final stage

Single Sided Circuits

Using grounded grid technique with single sided circuits and placing the tuning elements below the valve anode, a very compact arrangement is obtained (Fig. 3) wherein the R.F. current returns symmetrically on the inside of the cabinet and direct radiation from this stage is reduced to a minimum. The enclosing cabinet is also used as the air duct and with the air exhausted from the lower end of the cabinet, the air stream successively cools the filament and grid seals of the valve, the valve anode, and finally the tuning elements of the anode circuit.

Compared with push-pull circuits, the R.F. voltage across the tuned circuit, and the R.F. current circulating in that circuit are considerably reduced. Thus the conductor size can be smaller, and does in fact make variable coils of power amplifiers a practical proposition.

Again compared with a balanced circuit the number of paths for spurious oscillations is considerably reduced. The effect of this is so marked that no anti-squegger devices are required on the power stages of the transmitter which will be described later.

The disadvantage of obtaining a balanced output from a single sided circuit can be overcome by a tuned link circuit which also serves as an attenuator of harmonic and unwanted frequencies.

Output Circuit

The output circuit must be capable of giving a balanced output from the unbalanced output of an unbalanced final stage, it must cover 27·5-4Mc/s, and be cable of matching feeder impedances from 100Ω to 1 200Ω over the frequency band. It must also be capable of giving good rejection of harmonics.

These requirements were met by using a magnetically coupled output circuit followed by a π-coupler. Partial balance is obtained by earthing the centre point of the tuned capacitor and by earthing the centre point of the capacitor which is across the feeder. (See Fig. 4).

With the type of adjustable anode circuit used, and with the coupling coil wound centrally around the anode coil, it is not easy to obtain sufficient variation in mutual inductance between these two coils to meet the different feeder impedances. Consequently the coupling coil position has been fixed and output loading adjustment must be obtained by other means. By using the π-coupler after the tuned circuit, it is possible to obtain variations in output loading by adjusting the series coils in the π-coupler. It can readily be seen that the π-coupler enables a wide band of feeder impedance to be accommodated in that it is possible to raise or lower the impedance across the tuned circuit by simply adjusting the coils.

In practice, it has been found that 200Ω balanced or 600Ω balanced feeders can be accommodated over the

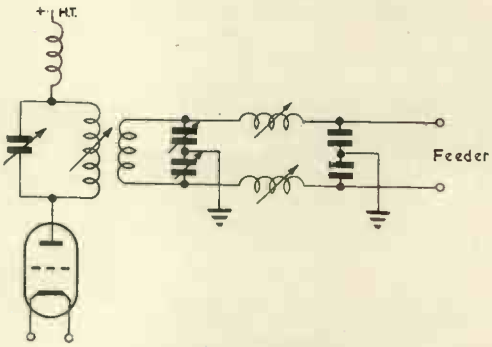


Fig. 4. The output circuit

whole frequency band with a 2-1 standing wave ratio without any switching adjustment whatever. Further, if a 75Ω unbalanced feeder is to be used, it is connected to one side of the circuit, leaving the other side free. The effect of this is to give 300Ω impedance across the circuit and so 75Ω feeder (unbalanced) can also be accommodated. Using this output circuit, for small changes of loading or feeder impedance it is only necessary to adjust the π-coupler coils and the anode circuit tuning, for the effect on the output circuit tuning is very small. Should it be necessary to make a large change in loading conditions then the output circuit must be retuned, but this is an exceptional requirement.

The use of the π-coupler gives an appreciable attenuation to the harmonic frequencies in addition to that provided by the coupled circuits.

Power Supplies

Valve types for the transmitter were selected so that only one high voltage supply is needed. This is 8kV, all other anode supplies being 500V or less.

Because of their long life and reliability the English Electric Ignatron type AR63 was selected for the main H.T. supply. These valves are grid controlled, half wave, mercury pool rectifiers and six are used for three-phase full wave rectification.

The grid control facility permits switching on of power in steps of one-third, two-thirds and full voltage, and the operation of high speed overload tripping with automatic resetting, all this being achieved by the use of Post Office type relays. The only contactor of any size used is one triple-pole slow-acting isolator which normally operates off load.

The smoothing circuit of the main rectifier uses a single stage with small inductance and large capacitance to give low transients to the varying load.

Filament supplies to the directly heated filaments are by metal rectifiers. Direct current heating is necessary to keep phase noise within required limits.

MOTORIZED CONTROLS

There are fifteen control shafts which require operation for tuning the transmitter. These are divided into four basic categories.

(a) Low torque, multi-turn, requiring accurate setting.

(b) Low torque, single turn, requiring accurate setting.

(c) High torque, multi-turn, requiring not extremely accurate setting.

(d) High torque, single turn, requiring not extremely accurate setting.

All these types of shafts are operated by variants of a basic motor " head " design.

It was decided, bearing in mind the need for adequate service facilities, that internal to the transmitter mechanical complexity should be avoided, and the complete driving mechanism of motor, electro-magnetic clutch, pre-selector cams and potentiometers for remote tuning indication should be mounted on a detachable panel, screwed on to the front panel of the transmitter, and connected to it by quick release plugs.

Accordingly four versions of the so-called " motor head " were produced to meet the four requirements already described under (a), (b), (c) and (d).

For the (a) condition the motor head uses two clutches and two cam selectors, one being used to select the particular turn and the other to select the required part of the turn. This arrangement permits high speed operation over most of the travel and low speed for the final selection.

For (b) condition only one clutch and one cam are used. In both (a) and (b) conditions the pre-selecting relays are wired to the clutches via the cam selectors, while contacts on the clutches control the motor circuit. Thus motor overrun does not affect accuracy. Where torques were particularly light and where inertia of the moving parts tended to cause overrun, the torque was purposely increased by friction brakes.

Where extreme accuracy of setting is not necessary the clutches have been dispensed with and the cam selectors operate direct on the motors.

Most of the control shafts have to be reversed during tuning and this is done by using limit and reversing switches on the motor head assemblies.

To ensure accuracy of tune all tuning is done in the same direction so that any backlash can be catered for.

Continued tests showed that after wavechange the transmitter performance, as assessed by power output and measurement of intermodulation products, was repeated.

Description of Transmitter

The complete transmitter, with doors removed, is shown on page 237.

The complete structure is 20ft long by 3ft 9in deep and 7ft. high. The enclosure is built entirely of pressed aluminium panels and strips with a number of internal free standing units of angle iron frameworks mounting power supplies and control circuits, and aluminium boxes mounting the higher power radio frequency circuits.

External to this structure and in a fireproof room at the rear are the main power transformer, smoothing choke and capacitors, filament rectifiers and the automatic voltage regulator. The extractor fan for air cooling is housed external to the transmitter in its own room.

Starting from the extreme left-hand the transmitter comprises the following stages.

(1) Power input cubicle with isolator, fuses, control relays and contactors and the interlocked three handle switches for door locking, high tension earthing and " transmitter on " switching. Safety precautions are quite comprehensive, making it practically impossible to get access to any dangerous voltage.

(2) Auxiliary rectifiers, local control push-buttons and selector switches, metering of low power supplies, monitor convertor panel and half of the mimic diagram.

The transmitter can, at this position and the adjacent bay be tuned to any frequency in the band with the aid of the mimic diagram which displays the circuit with full metering and with indicator meters showing the physical setting of every tuning meter. A " manual-automatic " switch at this position permits automatic selection of any six pre-set frequencies to be made, while the "local-remote" switch will transfer wave selection and " on-off " control to a remote point. (The mimic diagram can be seen faintly in the photograph on page 237).

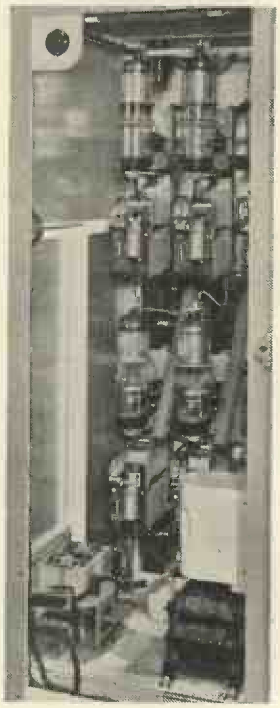


Fig. 5. Rear view of main rectifier

Fig. 6. Rear view of final amplifier

(3) The main rectifier (Fig. 5) is housed in this bay, on the front of which is the other half of the mimic diagram, the indicator lamp panel and an input test point.

(4) The six input mixer circuits, mounted in pairs, the early low power linear amplifier and the high power tetrode circuit are mounted in this bay.

This tetrode stage has the same type variable inductors and variable capacitors as are used in the penultimate and final amplifiers.

(5) The penultimate amplifier, a grounded grid triode, and the circuits for radio frequency feedback occupy the whole of this cabinet.

(6) The final amplifier fills this bay. Fig. 6 shows the rear view of this cabinet and illustrates the compactness of the grounded grid stage which handles 30kW peak envelope

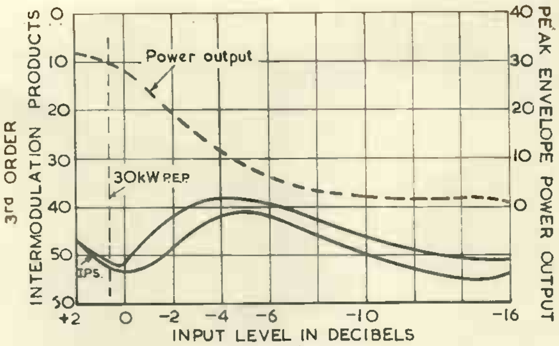


Fig. 7. Third order intermodulation products

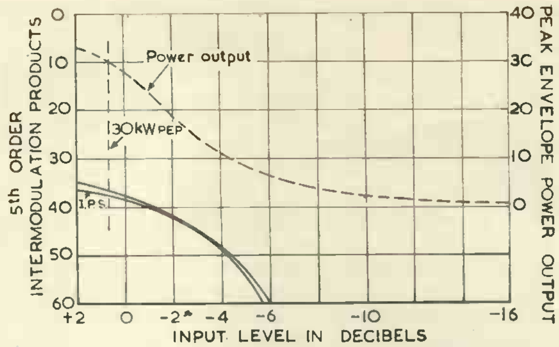


Fig. 8. Fifth order intermodulation products

power and is tunable from 4 to 27·5Mc/s and has only one tuning control for the whole stage. The stage is stable over this frequency range and no anti-squegger devices of any sort are necessary. Because of the weight of the valve used, lifting tackle, on runners, is built into this unit.

(7) Matching circuits to convert from the single sided circuit to balanced feeders are housed here. They permit tuning at 600Ω or 200Ω balanced or 75Ω unbalanced with standing wave ratios of 2/1.

(8) An access way to the back of the transmitter has been provided since it is intended that when multiple transmitters are used they will be installed butting end to end. This access way also provides symmetry of appearance.

Results

The performance of the prototype transmitter fully met the requirements specified.

Measurements of intermodulation products were taken for a large number of carrier frequencies and those for both the 3rd and the 5th order at a carrier frequency of 27·5Mc/s are given herewith (Figs. 7 and 8).

REFERENCE

BROWN, T. T. Harmonic Mixer Charts. *Electronics* (April 1951).

New Developments in H.F. Receivers

By F. W. J. Sainsbury*, Wh.Sch., A.C.G.I., D.I.C.

H.F. point-to-point communication systems vary in their requirements for a number of reasons, and at the receiving end of the system it is not practical to meet the various requirements with one type of receiver only. This article describes a range of receiving equipments recently developed with a view to meeting the various requirements both technically and economically.

THE circuits handled in most receiving stations will show a considerable variation in character, chiefly in the matter of importance, amount of traffic, degree and type of radio distortion and presence or otherwise of interfering signals. Obviously, various combinations of these characteristics can exist, but it is convenient to divide circuits into three groups:

GROUP 1

This includes heavily loaded circuits of first importance whose frequencies are not subject to change and which must be maintained for the longest possible daily periods.

GROUP 2

Under this heading fall circuits which are not required for continuous operation, or which are not subject to very severe radio conditions.

GROUP 3

This includes comparatively easy lightly loaded circuits or those where a high standard of accuracy is not essential.

To meet these varying requirements with one type of receiver would mean that if the receiver was capable of dealing with the difficult circuits then it would be more than good enough for the easy circuits. This obviously would not be an economic arrangement in spite of the standardization achieved.

A range of receivers has been developed therefore so that receiving stations may be equipped on a sound economic as well as a sound technical basis.

Group 1. Telegraph

The first of these, a double diversity telegraph receiver, is intended for Group 1 operation. The points considered as the basis of the design were:

1. SERVICE

To be capable of being connected to a pair of spaced aerials for the reception of F.S.K. and on-off signals on any three frequencies in the range 3 to 27·5Mc/s, the change from one frequency to another and general operation to be effected by the minimum number of controls. At the same time the design should provide for continuous coverage of the whole frequency range.

The output to be capable of operating a teleprinter, undulator, or tone sender.

2. PERFORMANCE

This to be the best possible so that the receiver will operate successfully for long periods with little or no

* *Marconi's Wireless Telegraph Co., Ltd.*

attention even though signal conditions are poor.

3. Operation

Without sacrifice of performance the receiver should be capable of operation by comparatively unskilled staff.

Fig. 1 shows a receiver being set up for a particular circuit by a member of the technical staff. The doors are subsequently locked and the receiver handed over to the operating staff.

The block schematic is shown in Fig. 2, and it will be seen that the receiver is a double superheterodyne with first and second intermediate frequencies of 1 600 and 100kc/s respectively. Automatic frequency control is applied to the second frequency changer and the main selectivity is provided by crystal filters at 100kc/s. For on-off signals the two paths are combined in the common load of the third detectors and taken thence to the D.C. circuits and keying frequency filters. In the case of F.S.K. signals a path selector is used, the same path selector feeds the A.G.C. circuits for both types of keying.

While the general schematic is fairly conventional the circuits and general detail are not and it is proposed to detail the more important points.

Signal Frequency

The range of 3 to 27·5Mc/s is provided by three double diversity amplifiers covering 3 to 6·5, 6·5 to 14·5 and 14·5 to 27·5Mc/s, respectively. Each amplifier has two H.F. stages and all circuits are separately tuned.

Associated with each amplifier is a crystal oscillator which covers the whole frequency range, but to provide for cases where a particular crystal may not be immediately available, a variable *LC* oscillator is fitted.

The frequency range of this oscillator is 2 to 4Mc/s and multiplying circuits are used to extend the range to 32Mc/s. By careful electrical and mechanical design the setting accuracy of this oscillator is correct to within 1kc/s at the fundamental frequency and the temperature coefficient is not more than 5 parts in $10^6/°C$. Humidity variations have no effect on the stability. Normally, one of each type of amplifier is fitted, and frequency selection is achieved by switching the aerial input and I.F. output. Should two of the required frequencies be in the range of one of the units then that particular unit could be duplicated at the expense of one of the other types.

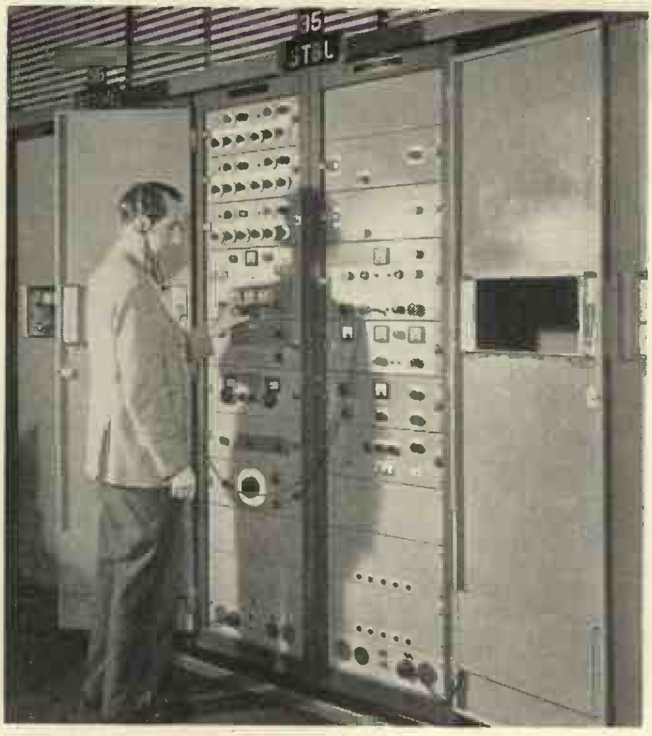
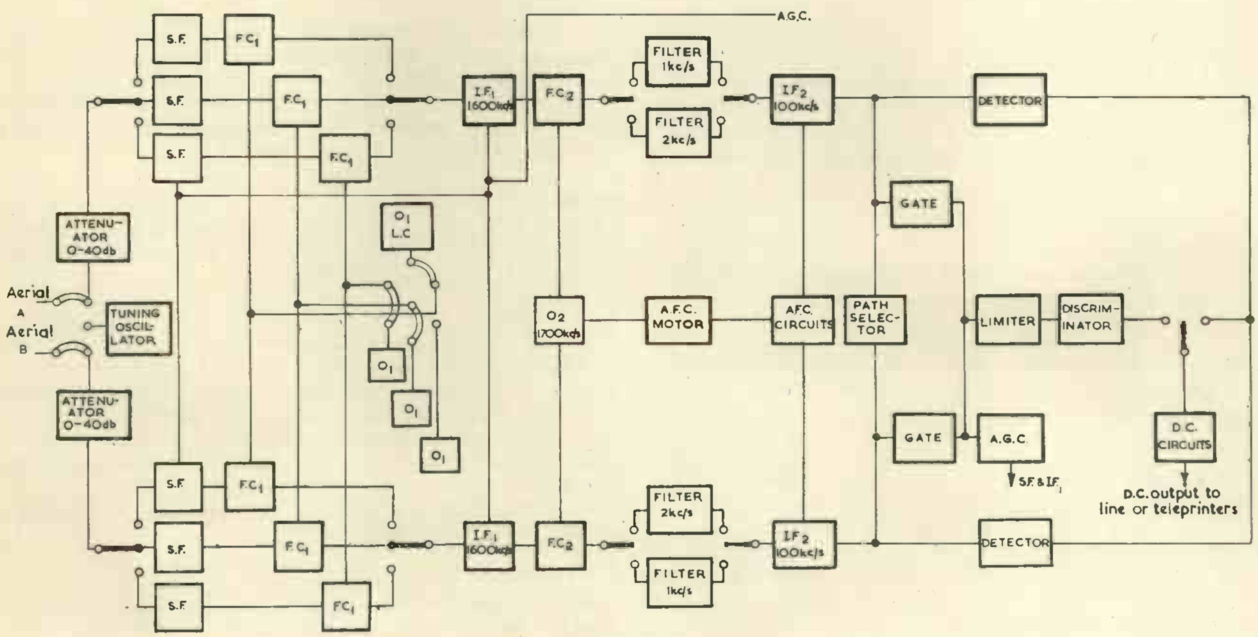


Fig. 1. Preset adjustments being made on the HR.91

Tuning of the H.F. circuits is facilitated by the provision of a tuning oscillator which can be patched into either aerial input at will.

In a receiver designed for central station working it is important that the radiation of the first frequency change oscillator is kept to an absolute minimum, otherwise spurious signals are created which may cause interference, and in certain circumstances mistune another receiver by operation of the automatic frequency control circuits.

Fig. 2. Simplified diagram of the HR.91



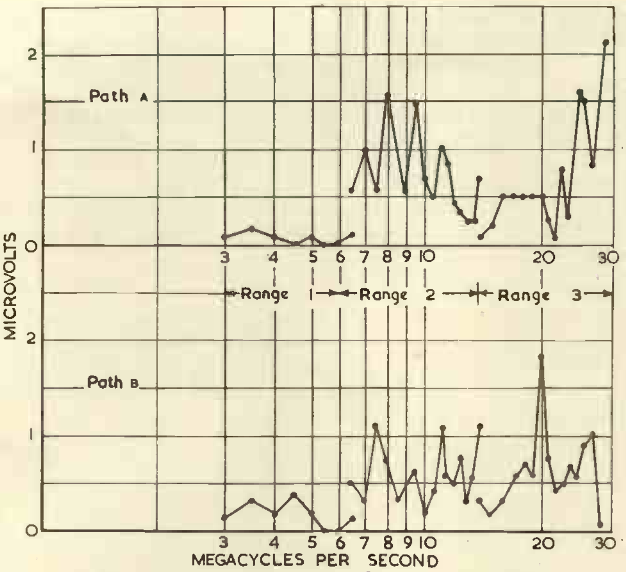


Fig. 3. Typical oscillator radiation figures (HR.91)

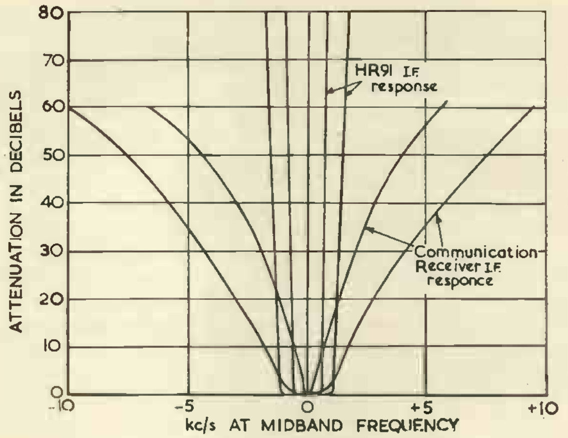


Fig. 5. Comparison of I.F. responses

Special precautions have been taken to minimize this oscillator leakage by careful attention to screening and decoupling. Fig. 3 shows, for a typical receiver the amount of first oscillator voltage leaking through to the aerial terminal.

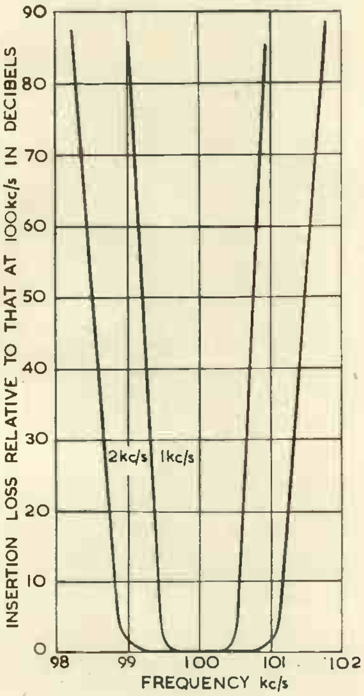


Fig. 4. Filter response (HR.91)

First I.F. Amplifier

The first intermediate frequency amplifier is centred at 1·6Mc/s and has a bandwidth of 8kc/s. This allows for a maximum signal spread of 2kc/s and a receiver drift of ±3kc/s.

Second Frequency Change Oscillator

The second frequency change oscillator, like the first oscillator, is designed for maximum stability and is comparatively unaffected by variations in temperature, humidity and supply voltage. Automatic frequency control is applied to this oscillator.

Second I.F. Amplifier

The second intermediate frequency amplifier is centred at 100kc/s and provides the main selectivity of the receiver. Alternative passbands of 1 and 2kc/s are provided by crystal filters whose response curves are shown in Fig. 4. The ratio of bandwidths at 80db and 3db attenuation is less than 2 to 1 and the performance is unaffected by temperature over the range 10° to 15°C.

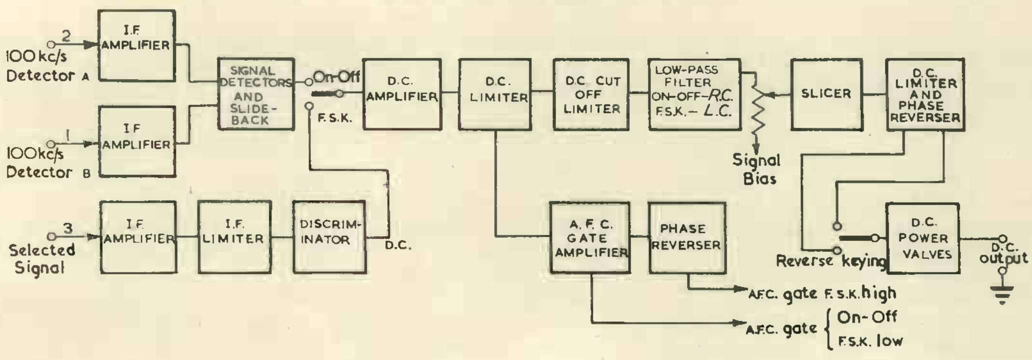
For comparison purposes the response curves of the 100kc/s filters has been redrawn in Fig. 5, together with selectivity curves of a good communications type receiver.

D.C. Circuits

For on-off keying, the output of the 2nd I.F. amplifier is taken to a diode rectifier, and combination of the two diversity signals is achieved by providing a common load for the two final rectifiers.

The D.C. amplifiers and limiters are conventional and low-pass filters serve to differentiate between keying and noise frequencies (Fig. 6).

Fig. 6. D.C. circuits of the HR.91



The overall characteristics of the receiver are such that on-off signals of sine wave formation varying in amplitude by 35db, are handled with negligible bias variation. This is shown in Fig. 7 and it is interesting to note that over the range of signal strengths shown the level at the final detectors varies from 4 to 400 volts. No automatic gain control is used for this test.

The recording threshold is the steady input necessary to change the current output from a clean space to a clean mark and is a static test. Under this condition the first limiter is not fully operative and some bias variation will be present when the signal is keyed, from the curve it will be seen that zero distortion is reached, i.e. the limiter is fully operative, when the input has been increased by approximately 5db. This gives the ratio between the static and working sensitivities for the keying formation and speed considered. If the signal is "square," i.e. is not curbed, then the static and working sensitivities should be identical. In practice, however, due to the build-up time of the I.F. filters, some curbing is introduced and the ratio is of the order of 1 or 2db.

For frequency shift keying, a path selector is used to select the strongest signal which is then fed to a limiter discriminator and then to the D.C. circuits.

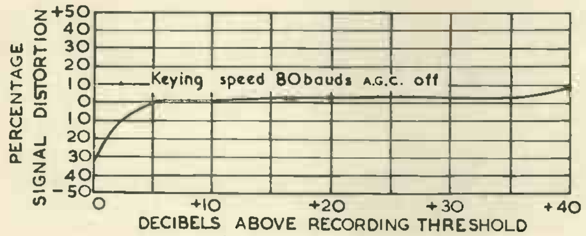


Fig. 7. Signal bias variation (HR.91)

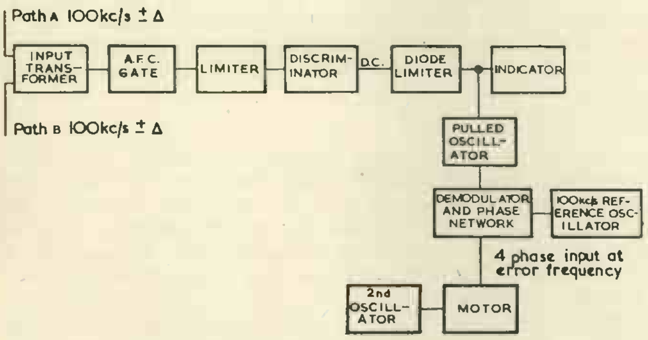


Fig. 8. Automatic frequency control (HR.91)

A.G.C.

The A.G.C. circuits are also fed from the selected output and the A.G.C. control voltage is variable both in amplitude and time-constant, so as to cater for the type of keying and speed of fading. For on-off keying very little A.G.C. action is used, it being found preferable to rely on the overload characteristics of the receiver. A time-constant of 100msec is a usual value. Rather more A.G.C. action may be used for F.S.K. signals.

A.F.C.

The A.F.C. system is shown in block schematic form by Fig. 8. The purpose of the gate valve is to prevent operation of the A.F.C. system by noise or interfering signals in the case of on-off keying and to select the required control signal in the case of F.S.K. signals. The control voltage is obtained either from one of the D.C. limiter stages, or from the signal discriminator. For the latter case a reversing stage is included so that the A.F.C. is controlled by either the mark or the space frequency.

The A.F.C. discriminator is centred at 100kc/s for on-off keying and is varied to suit the shift value for F.S.K.

After limiting, the discriminator output is used to pull the frequency of a crystal oscillator. This is achieved by varying the mutual conductance of a reactance valve connected to the crystal oscillator via a quarter wave network.

A four-phase output is obtained from the difference frequency between the pulled and reference oscillators and is applied to an impulse type motor which is geared to vary the frequency of the second oscillator.

The speed of the motor is a function of the error frequency so that no overshoot is present such as exists with a system using a constant speed motor which is switched on and off. The resulting tuning accuracy is better than 10c/s.

CONTROLS

Reference to Fig. 1 will show that a large number of controls of various types is fitted, but the great majority of these are set to suit the particular circuit. When used as a three frequency pre-tuned receiver, the doors are closed and the only controls then accessible are:

1. Frequency selection switch.
2. Aerial attenuator in each path.
3. Fine tuning control giving variation of ±3kc/s.
4. A.F.C. on-off switch.
5. Signal bias.
6. Monitoring switch.

In addition 2 path level meters and the current output meters are visible.

Group 1. Telephone

The corresponding Group 1 telephone receiver is the type HR.93. It follows the basic principles of the first receiver except that it is designed for non-diversity reception of independent, single, and double sideband telephony transmissions. A total of six preset frequencies is allowed for.

The main design points in a S.S.B. receiver are:

1. ACCURACY OF TUNING

This is especially important when using a local carrier when a frequency error of not more than a few cycles can be tolerated. This calls for very stable frequency change oscillators, and an automatic frequency control system which is accurate and will not mistune the receiver during periods of fading.

2. SENSITIVITY

So that full advantage may be taken of a quiet receiving site and directional aerials, the receiver sensitivity in terms of signal input for a given signal-to-noise ratio should be good. Furthermore, the signal-to-noise ratio should increase progressively as the signal strength increases, this is particularly important for rebroadcasting.

3. SELECTIVITY

The present-day close spacing of frequency allocations demands that each channel should occupy the minimum possible bandwidth. On the other hand, quality considerations demand that the channel should be as wide as possible.

It follows, therefore, that the ideal selectivity curve should be square, i.e. uniform response in the passband with extremely rapid rate of cut-off outside the passband. To minimize the possibility of interference and cross modulation effects it is important that the passband should not be wider than necessary, ideally it should be adjustable to suit the transmission.

4. OVERALL FREQUENCY RESPONSE

When two subscribers are connected via a land and radio telephone link, a great many pieces of apparatus are involved, each with its frequency response. If the overall frequency response of the link is to be reasonable, then the performance of each individual piece of apparatus must be of a high standard.

The simplified block diagram is shown in Fig. 9. It is similar to the first receiver in that the double superheterodyne principle is used with first and second intermediate frequencies of 1·6Mc/s and 100kc/s respectively. Automatic frequency control is applied to the second frequency changer and the separation of the sidebands and carrier is effected by crystal filters at 100kc/s. Both local and reconditioned carrier facilities are provided.

It will be noticed that the general schematic is not novel, the interest lies in the detail and this will now be described briefly.

Signal Frequency

This follows the pattern of the HR.91 except that the number of preset frequencies now totals six. The same types of signal frequency amplifiers, crystal oscillators and stand by variable oscillator are used.

amplifier depends on the filter bandwidth, the tendency is to make the filter as narrow as possible. The bandwidth adopted represents the limit when such points as ease of tuning and stability with temperature and other variables are considered. The gain of the amplifier is variable to suit the various degrees of carrier suppression used, and the output is limited so as to present a fixed level at the demodulator.

Sideband Filters

Alternative bandwidths of 6kc/s and 3·5kc/s are provided for each sideband, selection being by means of coaxial U-links. Typical response curves of the upper sideband filters are shown by Fig. 11 and are summarized in Table 1.

The figures given are substantially constant over the temperature range of 10 to 50°C and are independent of varia-

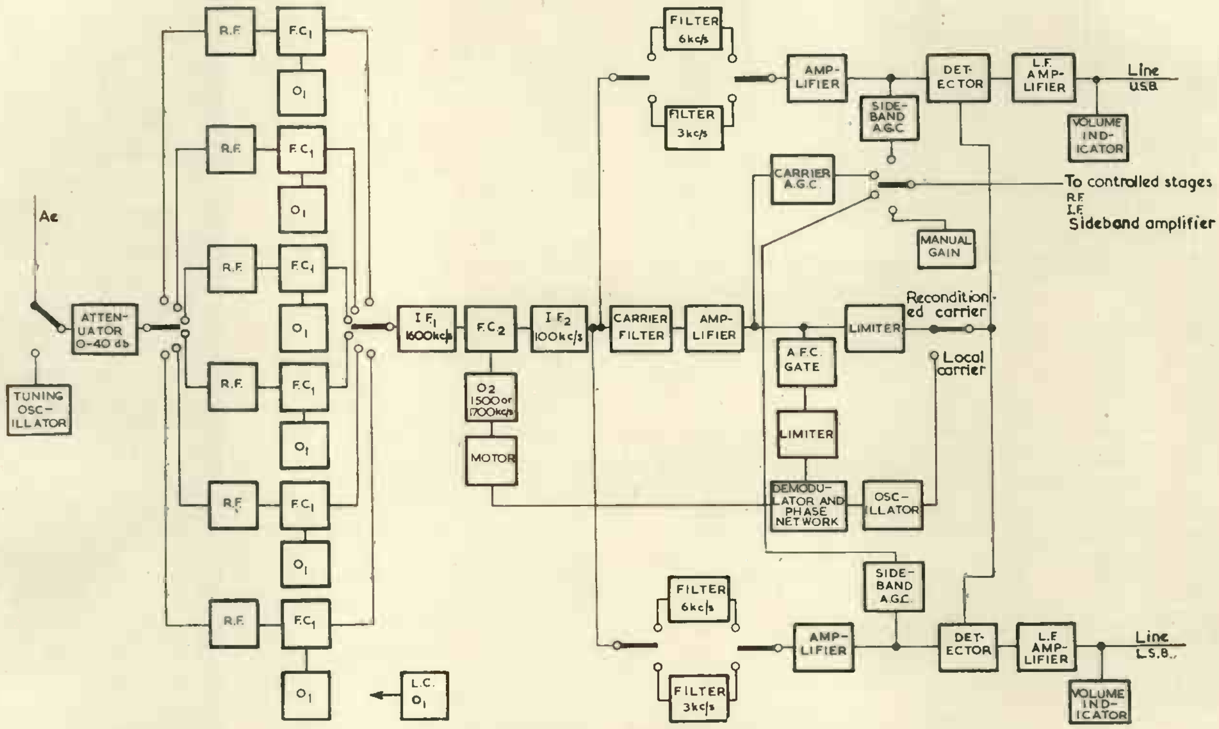


Fig. 9. Simplified diagram of HR.93

First I.F. Amplifier

The total bandwidth of the amplifier is 18kc/s, this is necessary to allow for the reception of a transmission with two 6kc/s sidebands and the possible variation of ±3kc/s introduced by the fine tuning or A.F.C. of the second oscillator.

Second Frequency Change Oscillator

By means of a switch control, this may be set either to 1·5Mc/s or 1·7Mc/s to meet the convention of sideband positioning above and below the signal frequency of 10Mc/s, A.F.C. or manual control may vary this oscillator by ±3kc/s.

Carrier Amplifier

This is centred at 100kc/s and is preceded by the carrier filter whose response is shown in Fig. 10, the filter bandwidth is 60c/s at 2db.

As the signal-to-noise ratio at the output of the carrier

tions in humidity and reasonable mechanical shock. To prove the latter point a prototype filter has been subjected successfully to the instrument vibration test specified in K.113.

Automatic Gain Control

The output of the carrier amplifier, before limiting, is used to operate the automatic gain control circuits. The valve stages controlled are the second R.F. stage, two stages in the first I.F. amplifier and one stage in the second I.F. amplifier.

During periods of selective fading it is obvious that the carrier level does not follow the fading of the sidebands, and for this reason the carrier A.G.C. is given a long time-constant. A constant volume amplifier is then necessary between the receiver output and the input to the telephone terminal.

Where the sideband signal consists of frequency modulated tones, either for facsimile or telegraphy, then sideband operated A.G.C. can be used with great advantage.

Automatic Frequency Control

The carrier amplifier output is taken via a gate valve to a limiting stage and thence to a mixer stage where it is compared with the 100kc/s standard oscillator. The output of the mixer stage, which is the difference or final error frequency, is taken to a phase-splitting network and is then used to operate a four-phase impulse type of motor which controls the second frequency change oscillator.

As this system depends upon the direct comparison of two frequencies, and the correcting system operates at a speed proportional to the difference frequency, the overall accuracy is very great and the final error is, for all practical purposes, zero.

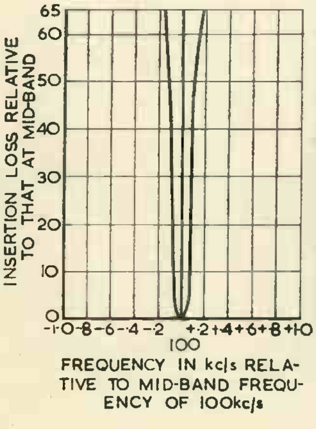


Fig. 10. Carrier filter response (HR.93)

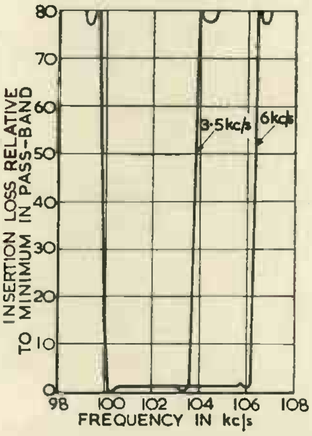


Fig. 11. Upper sideband filters (HR.93)

TABLE 1

Response of Sideband Filters

FREQUENCY (c/s) (fc = 100 000 c/s)		DISCRIMINATION RELATIVE TO MEAN INSERTION LOSS IN PASSBAND (Decibels)
UPPER SIDEBAND	LOWER SIDEBAND	
$fc - 350$ and below $fc - 200$ $fc - 100$	$fc + 350$ and below $fc + 200$ $fc + 100$	Not less than 75 " " 45 " " 25
FOR 6kc/s BANDWIDTH $fc + 100$ to $fc + 6\,000$ $fc + 6\,520$ and above	$fc - 100$ to $fc - 6\,000$ $fc - 6\,520$ and below	Not more than ± 1 Not less than 75
FOR 3·5kc/s BANDWIDTH $fc + 100$ to $fc + 3\,500$ $fc + 4\,020$ and above	$fc - 100$ to $fc - 3\,500$ $fc - 4\,020$ and below	Not more than ± 1 Not less than 75

The purpose of the A.F.C. gate valve is to render the A.F.C. circuits inoperative by noise when the carrier fades below a certain predetermined level.

Group 2. Telegraph

A telegraph receiver designed for Group 2 working is illustrated in Fig. 12 and the block diagram is given in Fig. 13. The type title is HR.11.

It is designed like the HR.91 for double diversity reception of F.S.K. and on-off signals, but the change from one circuit to another may be effected more rapidly. The general facilities, oscillator stability and discrimination and selectivity are slightly inferior when compared with the HR.91, but improved discriminators and A.F.C. performance have been introduced so that values of shift down to 100c/s can be successfully dealt with. An overall selectivity figure of 500c/s is recommended when using the very low values of shift, and, with this arrangement, adjacent transmissions need not be spaced more than 1kc/s apart. This, of course, demands good transmitter stability and is probably achieved most easily by using frequency modulated tones spaced 1kc/s apart on one sideband of an I.S.B. transmission. For reception, the original carrier is ignored and a separate telegraph receiver used for each channel.

Signal Frequency

The range of 3 to 27·5Mc/s is covered by four conventional switched bands. Two stages of amplification are used and the tuning is ganged.

The first oscillator is separately controlled and for reasons of stability covers the limited frequency range of 2·7 to 5·2Mc/s, multiplying circuits being used to extend the range to match the signal frequency circuits. The maximum temperature coefficient is about 10 parts in $10^6/°C$.

As an alternative to the continuously variable oscillator, crystals, up to a maximum of 6, may be plugged in and selected by switch control.

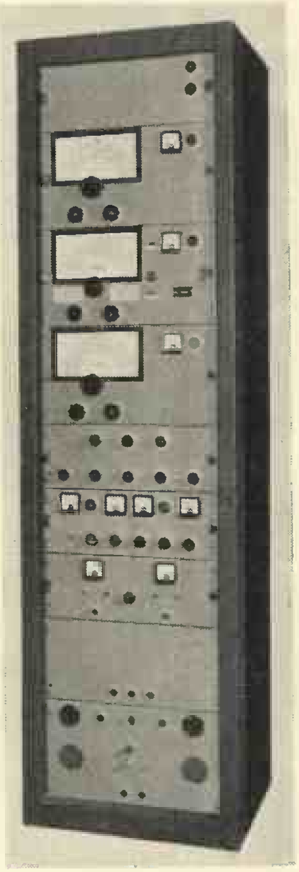


Fig. 12. The HR.11

First I.F. Amplifier

This is centred at 2·6Mc/s to give good image signal protection and has a bandwidth of approximately 10kc/s.

Second I.F. Amplifier

Two crystal filters, centred at 100kc/s, are connected in series to provide the narrow passband, one of the filters being switched out of circuit when the wide passband is required. There are two editions of the receiver, one is fitted with filters to give alternative passbands of 1kc/s and 2kc/s, and the other edition uses different filters which provides alternative passbands of 0·5kc/s and 1kc/s.

Fig. 14 shows the response curves of the three filter arrangements. Care has been taken to obtain good transient responses, especially in the case of the narrow filter.

On-off Signals

For on-off signals the output of each 2nd I.F. amplifier is taken from a power amplifier stage to a diode detector, the outputs of the two detectors are combined in a common load in the conventional manner. Two independent current outputs of 30-0-30mA are provided so that the simultaneous operation of an undulator and a teleprinter, or two teleprinters is possible.

F.S.K. Signals

For F.S.K. signals, outputs from the 2nd I.F. amplifiers prior to the power output stages are changed to 10kc/s, path selection is effected at D.C., but is controlled by the signal levels at 100kc/s. By this means greatly increased sensitivity and stability are obtained for

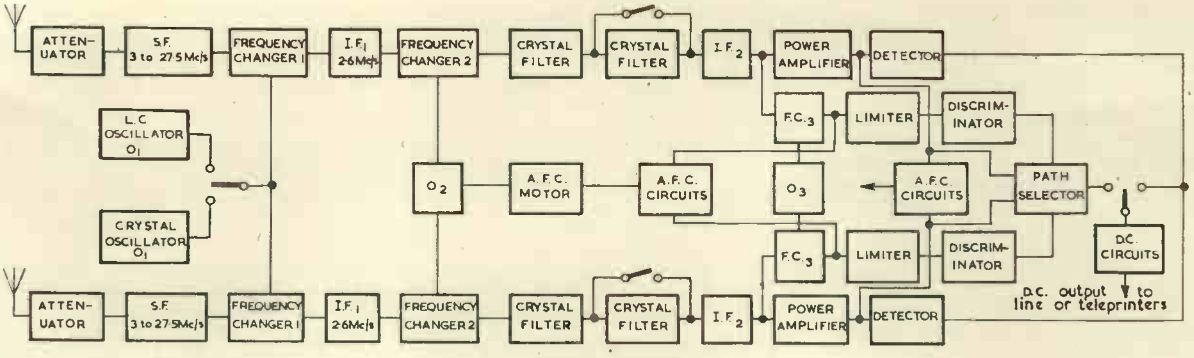


Fig. 13. Simplified diagram of HR.11

the signal and A.F.C. discriminators, and enables shift values down to 100c/s to be successfully handled.

Automatic Frequency Control

The block schematic of the A.F.C. system is shown in Fig. 15. An output at 10kc/s is taken to a separate limiter and discriminator, the tuning of the latter being variable in switched steps to cater for shift values of 100, 140, 200,

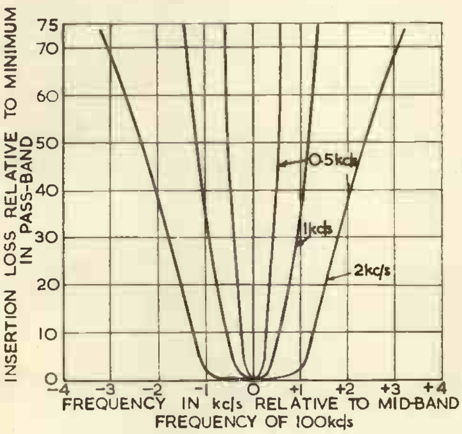


Fig. 14. Filter responses (HR.11)

280, 400, 560 and 840c/s. The use of intermediate values may give rise to a slight amount of signal bias, but this is easily corrected by adjustment of the bias control.

The D.C. output from the discriminator is fed, to a ring modulator. A tone input at 400c/s is fed simultaneously to the modulator and to one winding of a two-phase motor, the latter is mechanically coupled to a small variable capacitor forming part of the tuned circuit of the 2nd frequency change oscillator.

The tone output from the modulator, which varies in magnitude and phase according to the magnitude and polarity of the discriminator output, is taken through a gating stage to an amplifier and then to the other winding of the two-phase motor. The gating stage is keyed from the limiter in the D.C. circuits, and prevents operation of the A.F.C. system by noise or other causes during long rest periods in on-off keying.

Automatic Gain Control

The A.G.C. system is adjusted to operate for signals which are within 20db of the level necessary to cause overloading, and is not applied to the signal frequency stages until the gain of the 1st I.F. amplifier has been reduced by 20db. This latter precaution is necessary to avoid degrading the signal-to-noise ratio.

A single switch provides simultaneous variation of the A.G.C. intensity and time-constant so as to cater for various types of keying and degrees of fading.

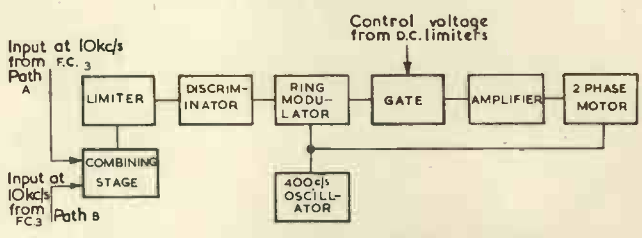


Fig. 15. Automatic frequency control (HR.11)

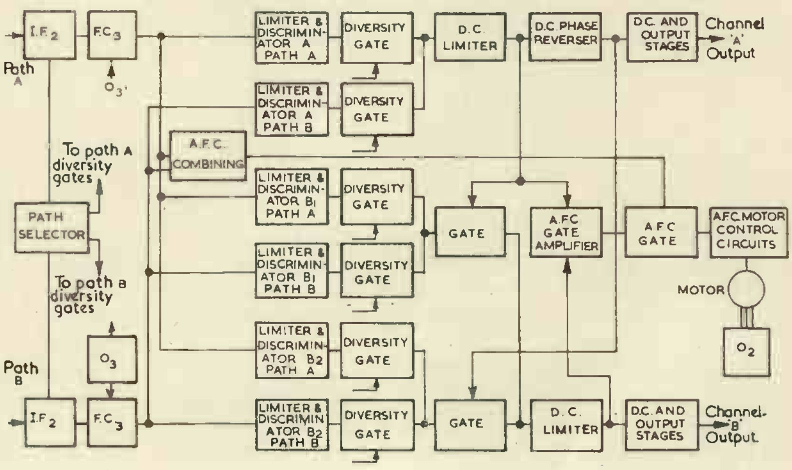
By adding an extra unit, the HR.11 receiver may be adapted for the reception of two channel frequency shift or Diplex signals. The block schematic is then as shown in Fig. 16.

Group 2. Telephone

The companion to the HR.11 for telephony working is is shown in block schematic form by Fig. 17. The type title is HR.21. The circuit arrangement is similar to the HR.93 except in the following respects:

1. The H.F. circuits are ganged for tuning purposes and conventional range switching is used.
2. The frequency stability of the 1st oscillator is slightly inferior, it varies between five and ten parts in $10^6/°C$

Fig. 16. Inclusion of diplex on the HR.11



over the frequency range. The setting accuracy too, is inferior.

3. There is no tuning oscillator since tuning of the ganged R.F. circuits is comparatively easy.
4. The first I.F. amplifier is centred at 2·6Mc/s so as to maintain a good image signal protection in spite of any small ganging inaccuracies which might exist.
5. Provision is made for one bandwidth only, 6kc/s being adopted as the standard for both upper and lower sidebands, 3·5kc/s filters may be fitted instead if required. The performance of the filters is identical with those fitted to the HR.93.
6. Sideband A.G.C. is not provided.

From the foregoing it will be appreciated that the changes are largely in the nature of facilities and that the overall performance is only slightly inferior to that of the HR.93, the receiver is thus eminently suitable for all but the most difficult telephony transmissions.

Group 3. Telegraph

A telegraph equipment to deal with the easy circuits classified as Group 3 need only be comparatively simple in character, and relatively cheap to manufacture. There is, sometimes, a tendency to condemn such an equipment when it fails on the more difficult circuits, but a little thought will show that this criticism is unfair.

A simple form of double diversity recording unit is shown in schematic form in Fig. 18 and illustrated in Fig. 19. The type title is HU.12. It is intended for operation with two communication type receivers and its performance, as may be expected depends to a large extent on the frequency stability and selectivity of the particular

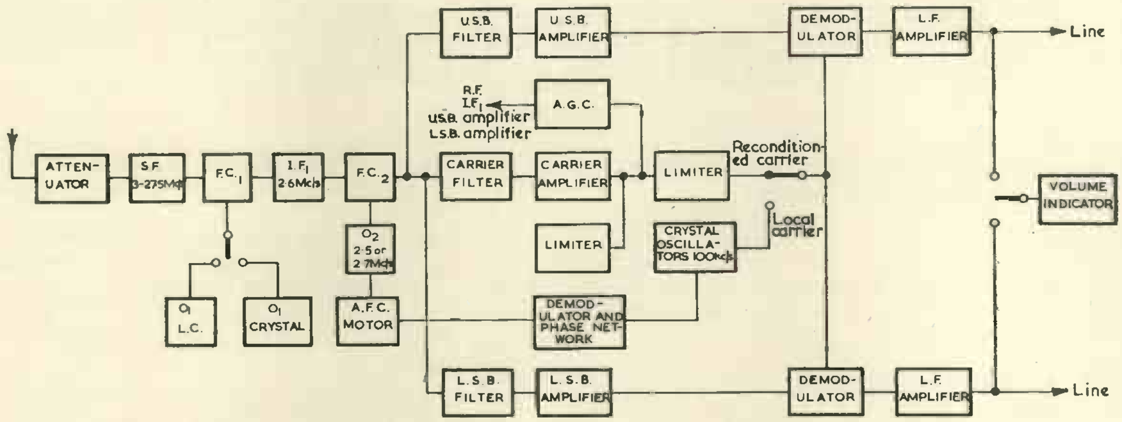


Fig. 17. Simplified diagram of the HR.21

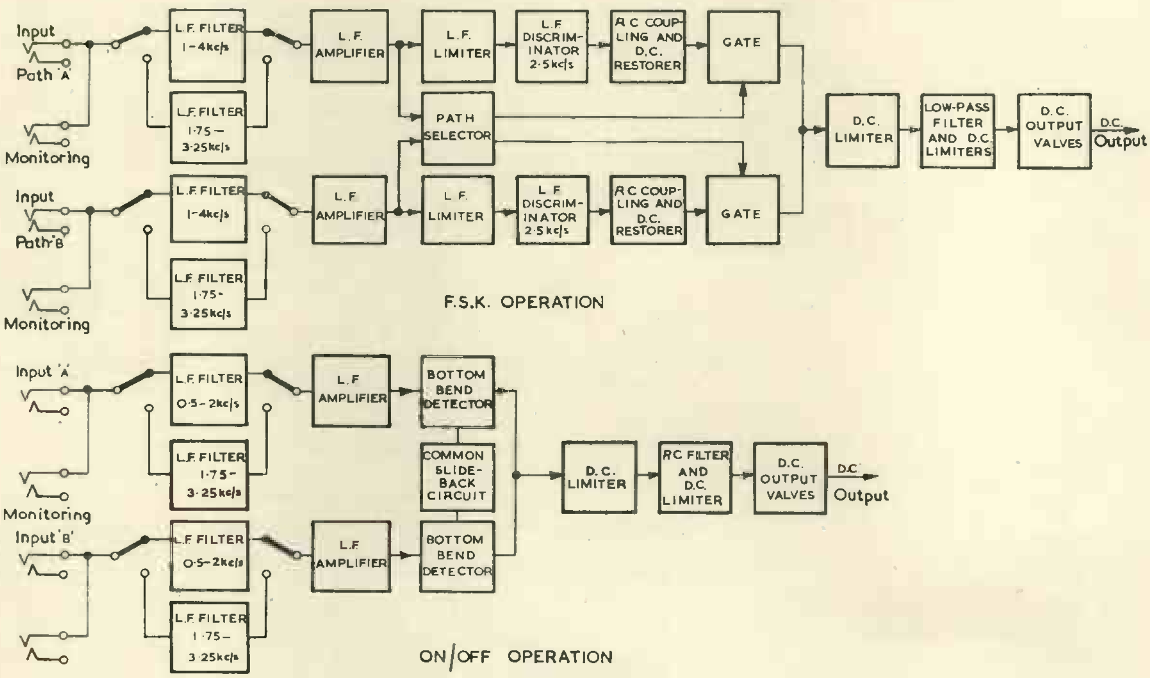


Fig. 18. The HU.12

Fig. 19. The HU.12

receivers used. No modifications are necessary to the receivers.

F.S.K. Operation

The B.F.O. of each receiver should be offset from the mid-frequency of the I.F. amplifier by 2·5kc/s and the L.F. gain controls set so that the receiver output level as determined by the A.G.C. system is about +5dbm. The minimum input level to record is about −25dbm so that the equipment will handle quick fades of the order of 30db.

To minimize the effect of receiver drift a wideband discriminator is used, the output being capacitively coupled and clamped by a D.C. restoration circuit. As a result, the signal may drift ±800c/s before retuning is necessary, but a preliminary warning is given by a simple flashing neon light system.

Combination of the two received paths is effected at D.C. and is controlled by a selector operated by the signal levels before limiting.

The equipment will handle frequency shift values between 400 and 1 000c/s the maximum keying speed is 120 bauds, but the keying filters may be switched to give optimum noise protection at normal teleprinter speed.

On-off Operation

It will be seen that the circuit adopted is conventional, diversity combination of the signals is achieved by the use of a common load for the two bottom bend detectors.

The receiver output may be centred at 1 000c/s in the usual way or may be adjusted to 2 500c/s to facilitate change-over from on-off to F.S.K. reception.

Group 3. Telephone

A Group 3 telephony receiver is illustrated in Fig. 20 and shown in block diagram form in Fig. 21.

It will be noticed that the circuit follows a conventional S.S.B. practice, but the mechanical size is that of a normal communication type receiver. This has been achieved by relaxing the performance somewhat in the following respects:

1. The signal frequency and variable oscillator circuits are ganged.
2. Provision is made for the reception of one sideband only; this, however, may be switch selected.
3. The skirts of the response curve of the sideband filter are not so steep as for the HR.93 and HR.21.
4. The overall frequency response is not so good.
5. The first oscillator stability is of the order of 30 parts in $10^6/°C$.

Brief Circuit Description

The signal frequency range of 2 to 30Mc/s is covered in four switched bands and two stages of radio frequency amplification are provided. The first frequency change oscillator may be either variable or controlled by any one of six crystals.

The first I.F. amplifier is centred at 1·6Mc/s and the second at 100kc/s, the second frequency change oscillator may be set either to 1·5 or 1·7Mc/s according to which sideband is required.

The remainder of the circuit is obvious from the diagram, responses of the sideband and carrier filters are given by Figs. 22 and 23 respectively. Provision is made for reconditioned carrier only, and as this does not call for such accurate tuning as in the case of local carrier operation, the carrier filter is relatively wide.

Automatic frequency control is applied to the second frequency changer through a reactance valve, which in turn is fed from a crystal discriminator. Frequency drifts up to ±3kc/s are corrected to within 10c/s by this system.

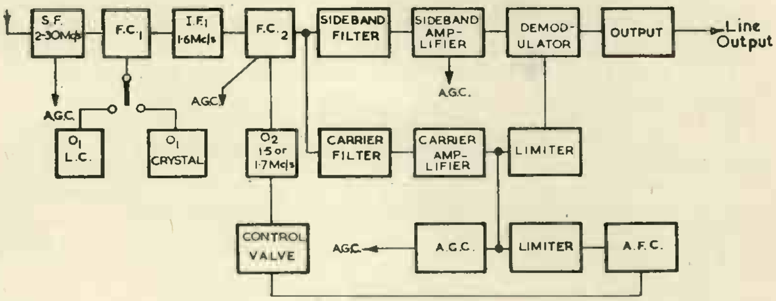


Fig 21. The HR.22

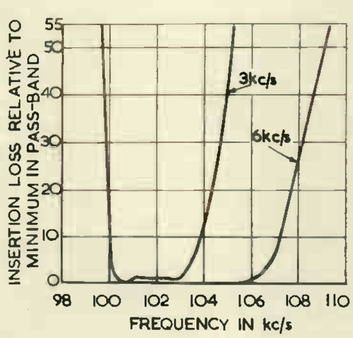


Fig. 22. Sideband filter (HR.22)

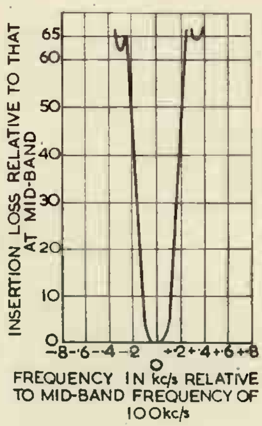


Fig. 23. Carrier filter (HR.22)

Fig. 20. The HR.22

1·5 to 30Mc/s at Sea

By D. J. Spooner*

The allocation of frequencies for marine use, the operation of the British Area Scheme and the short-range radiotelephone system operated in British home waters are delineated and the manner in which these facilities are used by the deep-sea trawler is described.

THE International Radio Regulations, drawn up at the International Telecommunication Convention at Atlantic City in 1947, allocate for the use of ship stations the following frequency bands between 1·5Mc/s and 30Mc/s:

For medium-range radiotelephony (and radiotelegraphy to ships with qualified operators) 1·6Mc/s to 3·7Mc/s. This is known as the Intermediate (I.F.) or Radiotelephony (R.T.) band. For long-range radiotelegraphy narrow bands in the region of 4, 6, 8, 12, 16 and 22Mc/s. These are known as the H.F. bands.

Radiotelephony is also permitted in parts of all except the 6Mc/s H.F. band, but the facility is little used by any except the larger passenger ships as a frequency tolerance of 0·005 per cent, which is beyond the capabilities of most marine transmitters, is imposed on radiotelephony transmissions.

The assignable H.F. radiotelegraph frequencies are tabulated below:

BAND (Mc/s)	15 FREQUENCIES PASSENGER WORKING		9 FREQUENCIES CALLING		98 FREQUENCIES CARGO WORKING	
	SPACING (kc/s)	WIDTH (kc/s)	SPACING (kc/s)	WIDTH (kc/s)	SPACING (kc/s)	WIDTH (kc/s)
4	2·5	40	1·0	8	0·5	48·5
6	3·75	60	1·5	12	0·75	72·75
8	5·0	80	2·0	16	1·0	96·0
12	7·5	120	3·0	24	1·5	145·5
16	10·0	160	4·0	32	2·0	192·0
22	10·0	140	5·0	40	2·5	122·5

The frequency tolerance demanded of radiotelegraph stations is 0·02 per cent which, it will be noted, is somewhat greater than the spacing of the cargo working frequencies. However, it is believed that, by assigning frequencies in rotation to the thousands of ships involved, interference will be avoided and better communications result.

A ship is assigned a minimum of one calling and two working frequencies in each of the H.F. bands. In the first five bands frequencies are assigned in harmonic sequence; so from three crystals oscillating in the region of 2Mc/s it is possible to derive a total of 15 frequencies. If the 22Mc/s band is used, a further three crystals are required.

Only keyed-carrier emission is permitted in the H.F. radiotelegraphy bands and the power radiated must not exceed 1kW.

These are the facilities allocated, by international agreement, to ship stations. The manner in which they are to be used by British ships is laid down in The Merchant Shipping (Radio) Rules, 1952, and in the Notices to Ship Wireless Stations issued from time to time by the General Post Office.

The Radio Rules are issued by the Minister of Transport. They divide British shipping into three classes and prescribe the nature of the equipment to be carried by each.

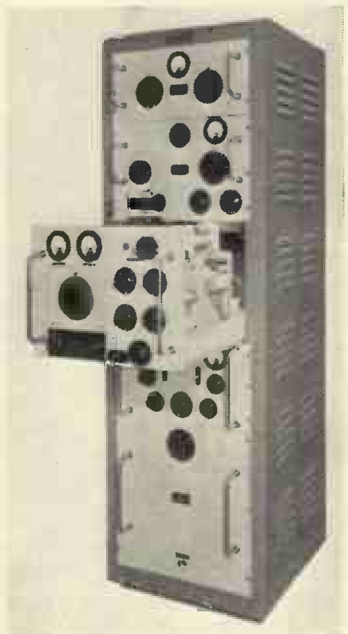
Class I includes all mechanically propelled ships which carry 250 passengers or more and are at sea for 16 hours or longer between consecutive ports.

Class II includes passenger ships other than those of Class I and cargo ships of 1 600 tons gross and upwards.

Class III ships are those of 500 tons and upwards, but of less than 1 600 tons.

The Rules do not apply to ships not propelled by mechanical means, cargo vessels of less than 500 tons, pleasure yachts or fishing boats.

Ships of Class I and Class II are required to carry a main transmitter and an emergency transmitter—both operating in the medium-frequency band, and a receiver covering the frequencies: 15kc/s to 20kc/s and 100kc/s to 25Mc/s. Ships of Class III are required to carry a radiotelephone installation if they are not equipped with a medium-frequency radiotelegraph installation.



Transmitter type G80 for deep-sea trawlers, etc.
405-525kc/s C.W. & M.C.M.
1·6-3·7Mc/s C.W., M.C.W. & R.T.
4, 8, 12, 16Mc/s C.W.

Although the fitting of H.F. transmitters and of R.T. equipment (except in the case of certain ships of Class III as mentioned above) is voluntary, to ensure that the available facilities are used to the maximum advantage of all, the nature of the equipment to be carried is prescribed. Before their apparatus may be fitted to any ship, manufacturers must submit it to the Ministry for type approval. To obtain a certificate of type approval, the apparatus must pass a series of tests to ensure that it will not, because of inadequate performance, waste the time of the coast stations or of other shipping.

For the purposes of long-range ship-shore communication by British ships, the world has been divided into a number of areas. Each area is covered by an area transmitting station from which traffic for British registered ships is sent during six schedules daily. These schedules are at the same times (G.M.T.) in all areas.

The area stations are:

TRANSMITTING STATIONS	RECEIVING STATIONS
Portishead	Portishead
Capetown	Capetown
Ceylon	Ceylon and Bombay
Wellington	Waiouru and Awarua
Vancouver	Vancouver
Sydney	Sydney
Singapore	Singapore and Hong Kong
Halifax	Halifax

* *Redifon Limited.*

A traffic list, in alphabetical order of call signs, is sent at the beginning of each scheduled period. This is followed immediately by the transmission of the relative radiotelegrams. Unless acknowledgment is received from the ship to which it is addressed, a radiotelegram is repeated in each of the five succeeding schedules.

In order that traffic may be routed through the correct area station, the latest information about shipping movements is essential. Ships are, therefore, required, when entering or leaving port or when changing areas, to notify the area station of their movements.

A ship wishing to communicate with a shore station must first call the station on the appropriate calling frequency. If an answer is not received within a short time, the call must be repeated. If the call remains unanswered, other receiving stations may offer to accept the traffic on behalf of the station being called. This does not affect the charge for the message because no charge is made for relaying messages from one area station to another. Thus, a ship wishing to send a radiotelegram to an address in London might call Portishead but might be answered by Capetown who would take his traffic and forward it to

An approved receiver for compulsorily fitted ships (Redifon type R50H)

Portishead, over the point-to-point radio network linking the area stations.

Having established contact with the area station, the ship's operator announces the working frequency on which he wishes to work. If this is agreeable to the area station, he is instructed to change to that frequency and send his traffic. Traffic is never sent on the calling frequency.

Around the coasts of the United Kingdom a short-range radiotelephone service is operated by the following coast stations:

Wick Radio	Niton Radio
Stonehaven Radio	Land's End Radio
Cullercoats Radio	Seaforth Radio
Humber Radio	Portpatrick Radio
North Foreland Radio	Oban Radio

The calling and distress frequency for this service is 2 182kc/s. Nine frequencies between 2 009kc/s and 3 373ks/c are allocated for the use of ships working with coast stations; each frequency being designated by a Channel Number. In general, a ship is assigned two channels. A further six frequencies are allocated for inter-ship communication.

Coast stations transmit traffic lists from four to six times daily, at fixed hours, on their working frequencies, after a preliminary announcement on 2 182kc/s.

A ship wishing to pass traffic to a shore station calls the station on 2 182kc/s indicating that he has a message to transmit on, say, Channel 2. The shore station replies on 2 182kc/s, telling the ship to transmit on Channel 2 and listen on . . . kc/s. Traffic is then passed on these frequencies.

There are three internationally agreed casualty and warning signals which are normally sent on 2 182kc/s. These are:

Signal	Use of Signal
"MAYDAY" is the DISTRESS SIGNAL	Sent three times when a ship is in danger and requires immediate assistance.
"PAN" is the URGENCY SIGNAL	Sent three times to indicate that a very important message is about to be sent concerning the safety of a ship or of some person on board.
"SECURITE" is the SAFETY SIGNAL	Sent three times to indicate that a gale or navigation warning is about to be transmitted.

Ship stations are expected to listen on 2 182kc/s for distress calls for three minutes at the beginning of each hour and half-hour. Coast stations are, of course, listening continuously on this frequency.

The urgency signal "PAN" followed by the word "MEDICO" is used to initiate a call for medical advice. A ship requiring medical advice may obtain it through any coast station. Where the request is made in the form of a message, the coast station passes it to the appropriate medical authority, whose reply is transmitted by the coast station to the ship. Where the radiotelephony "Link" service is available, the Master of the vessel may, if desired, be connected by telephone direct to the medical authority. No charge is made for this service.

Telephone communication with any shore subscriber (Link Service) may be obtained through any of the coast stations if within sufficiently close range. The maximum range at which link calls are accepted is, nominally, 150 miles, but with suitable equipment and under favourable conditions, calls can be made over much greater distances—500 miles or so.

The procedure for making a link call is as follows:

(a) Ship calls the coast station on 2 182kc/s stating "Telephone call channel . . . ."

(b) Coast station replies on 2 182kc/s and indicates the frequency on which it proposes to work.

(c) Ship transfers to the stated channel frequency and gives the name of the telephone exchange and number required.

(d) Coast station replies on the working frequency.

(e) Ship remains on watch until the telephone subscriber is connected or the coast station gives other instructions.

A subscriber wishing to communicate with a ship books his call through his local telephone exchange stating, if possible, the name and telephone number of the coast station with which the ship is expected to be in contact. The ship is then notified in the next traffic list that the call is booked.

To avoid the delay in making contact with the ship, the introduction of a selective calling system is under consideration. This would use a combination of audio frequency tones to actuate automatic alarm devices in individual ships.

In addition to the radiotelephone service, Wick Radio, Stonehaven Radio, Humber Radio and Oban Radio operate a radiotelegraphy service in the R.T. band and two frequencies are allocated for inter-ship radiotelegraphy. Wick Radio also provides a radiotelegraphy service on the 4, 6, 8 and 12Mc/s H.F. bands for the benefit of fishing vessels.

These are the facilities available to British shipping. How are they used by the various classes of ships ?

Large passenger ships make use of the whole range of facilities and the volume of traffic they handle, concerned not only with the working of the ship, but with the private and business affairs of the passengers, is enormous. From one of the trans-Atlantic liners it is possible, at any time during the crossing, to put through a telephone call to a subscriber on either side of the Atlantic. This traffic is now being handled by multi-channel single-sideband equipment. To enable the ship's newspaper to be produced, news is received by teleprinter and pictures by facsimile.

Most ocean-going cargo ships carry transmitters covering the six H.F. bands and delivering between 50 and 500 watts to the aerial. They are thus able to communicate with their owners from any part of the world and can be

50W radiotelephone with D.F. *for small fishing craft*

diverted, at short notice, to pick up any cargo which is available.

Many ships of this class are now being fitted with medium-range radiotelephone apparatus. This is proving to be a great saver of time by permitting ships' officers to arrange such matters as towage, fuel supplies, victualling etc., by direct telephone conversation with those concerned, while the ship is anything up to 500 miles from a port of call.

Many of the larger cargo ships as well as passenger ships are now fitting wideband aerial amplifiers and a system of concentric feeders to distribute entertainment programmes for the benefit of the crew. This system enables any member of the crew to use his own receiver in his cabin with the benefit of a really efficient aerial. Thus, the array of broom-sticks and bits of wire protruding from portholes, which were such an annoyance to ship owners and such a vexation to radio officers when they used the direction-finder, are no longer required.

The variety of craft using the R.T. band is legion and ranges from compulsorily fitted Class III ships to small fishing boats and private yachts. The aerial power of their apparatus varies from two or three watts to a maximum of 100 watts.

Unique among them all is the deep sea trawler; so, in conclusion, its equipment and the manner in which it is used will be described in some detail.

These ships sail to the Barents Sea and to Iceland and the coast of Greenland but, although some of them run to 600 tons and carry a crew of 27 hands, they are not, as fishing boats, compelled to carry radio. In fact they carry a radio installation more comprehensive than that of most cargo vessels for they depend to a great extent on their communication equipment for the size of their catch and the price obtained for it when it is landed.

One form of transmitter, which is very popular, covers the R.T. and M.F. and H.F. telegraphy bands. The whole equipment is housed in a single cabinet approximately two feet square and six feet in height. The power amplifier delivers 100 watts of carrier power to the aerial circuit on each band. Continuously variable frequency control is provided on all bands. The equipment may be operated either from the ship's 110 volt or 220 volt mains or from a 24 volt battery supply.

Generally two communication receivers are fitted—a main receiver, as type approved for use in compulsorily fitted ships, and a stand-by receiver. The main receiver covers 13kc/s to 26kc/s and 95kc/s to 32Mc/s. The stand-by receiver covers 350kc/s to 8Mc/s.

Besides a medium-frequency direction-finder for navigational purposes, a direction indicator operating in the R.T. band is carried. This gives a bearing accurate to within about two degrees and is used for keeping track of other vessels which are making successful hauls.

As these ships make use of the radiotelegraphy bands, they must carry certificated radio officers.

A round trip to the Barents Sea or to Greenland takes approximately three weeks—about a week each way sailing to and from the fishing grounds and about a week actually fishing.

On the way to the fishing grounds the duties of the radio officer are not particularly arduous. Throughout the day he will be occupied on the R.T. gathering information about the fishing from other ships returning from the fishing grounds. With many of these the skipper will talk via the extension microphone in the wheel-house.

There will be weather reports to gather and traffic lists to be taken. If his should be the commodore ship, two or three times a day, at fixed times, he must collect reports from all the other ships of the company's fleet and relay them to the owners. By this means, news of the whole fleet is conveyed to the owners in a single message which costs far less than would individual reports since inter-ship communication is free. This practice is also followed by the companies operating fleets of tramp steamers.

These reports are sent in private code for the information they contain may have a considerable effect on market prices.

There will, most likely, be private messages to handle for the crew for, as these men are ashore for only about 48 hours in every three weeks, much of their personal business is conducted by radio. They find flowers ordered by radiotelegram convenient for marking birthdays and other anniversaries; if they wish to back a horse, that, too, can be done by radio.

If the ship is bound for the Barents Sea she will probably steam inside the Lofoten Islands from Harstad to Honnigsvag and pilotage will have to be arranged by radio.

All this, with the care of the radar, echo-sounders and patent log, is enough to keep the radio officer pleasantly busy throughout the day, but leaves him sufficient time for meals.

As the fishing grounds are approached the pace quickens. The operator is now on duty for about 18 hours a day and most of his meals are taken at his post. Both communication receivers as well as the direction indicator are connected to the loudspeakers and tuned to different parts of the R.T. band to gather any hint of the presence of fish and the operator must be ready, at a moment's notice, to take a snap bearing on a successful rival. If the ship gets into a good run of fish, the skipper may order wireless silence so as not to attract other ships, but the listening watch will not be relaxed until the hold is full.

Acknowledgment

The author wishes to acknowledge the permission of Redifon Ltd. to publish this article.

Official Publications

(Obtainable from H.M. Stationery Office)

The International Radio Regulations Atlantic City 1947.
The Merchant Shipping (Radio) Rules, 1952.
Radio for Merchant Ships. Performance Specifications.
Radio for Merchant Ships. Performance Specifications for Compulsorily Fitted and Voluntarily Fitted Radio-telephones equipment.
The Post Office Guide.
Notice to Ship Wireless Stations No. 5 of the Year 1949; No. 2 of the Year 1953; No. 6 of the Year 1953.
Supplied free of charge for the use of Ship Wireless Stations.

H.F. Airborne Communication Equipment

By G. L. Warner*

H.F. equipment is now the only means of long range communication between aircraft and ground. The operational requirement for such equipment is discussed, leading to a brief description of a typical equipment fulfilling the requirement. Future trends in H.F. airborne equipment are also mentioned

THE use of the H.F. band as the principal means of long-range communication between aircraft and the ground has been continually increasing since the end of the last war until the use of the M.F. band, which was previously predominant, has virtually disappeared. Apart from the major consideration that communication in the H.F. band is more reliable, this change is due to several other factors, chief among these being the fact that M.F. transmitting equipment is fundamentally more bulky than its H.F. counterpart, and the R.F. voltages developed on the aerial system are such as to render prohibitive their use in high-flying aircraft.

Before dealing specifically with H.F. communication equipment, it is best to consider first some of the basic requirements for any airborne radio equipment. These are:—

(1) The equipment must be as light in weight and as small in size as is possible without jeopardizing its ability to withstand mechanical shock and vibration, and also the ease with which it can be maintained.

(2) The equipment must be capable of being operated with the minimum of controls. This is particularly so in the case of equipment which has to be controlled by the pilot of the aircraft, since in the first place the pilot has no time to operate controls which require precise adjustment, and secondly space in the cockpit is severely limited, and the controls must therefore be fitted into an extremely small panel area. In some cases, it is necessary for the equipment to be controlled from two distinctly separate points, for instance by the pilot and by the radio officer.

(3) Whatever its frequency band, the equipment should offer a number of pre-determined spot frequencies so that changes of frequency can be made in the minimum of time.

The above are the three main requirements for a piece of airborne equipment. Bearing them in mind, it is now possible to consider the operational requirements for an H.F. airborne communication equipment.

The equipment falls mainly into two classes:—

(a) For use in small aircraft of an all-up weight of the order of 20 000/30 000lb.

(b) For use in large trunk-route type of aircraft.

The basic requirements for the two classes of equipment are similar, the only difference being in detail.

* *Standard Telephones and Cables Ltd.*

Operational Requirements for H.F. Airborne Communication Equipment

Frequency Band

The frequency laid down for H.F. airborne communications by the Atlantic City Convention is 2·8-18·1Mc/s. A very great majority of frequencies lie in the band 2·8-12Mc/s, and for small aircraft an equipment covering this frequency band is usually adequate. Most communication is carried out on the same frequency from ground to air and air to ground. When differences in the two frequencies exist, they rarely exceed 5kc/s, and only occur on frequencies used for C.W. communication.

Type of Transmission

Transmission and reception on C.W., M.C.W., and R.T. signals is required. There is an increasing tendency towards the use of R.T. for aircraft communications, some schools of thought being directed towards converting all communications to this class of service so that the equipment can be operated by the pilot, thus obviating the need for a radio operator. Whether these extra duties can, in fact, be added to those which the pilot already has is not a question which should be discussed here.

Output Power

Operational experience has shown that for large aircraft an output power into the aerial tuning system of some 100-150 watts is adequate. It is also required that this power should be capable of being modulated 100 per cent for R.T. purposes. In modern high speed aircraft, however, it is becoming increasingly difficult, if not impossible, to provide conventional fixed wire aerials outside the skin of the aircraft. Aerials located within the contour of the aircraft, while ideal aerodynamically, are less efficient electrically, and therefore there may be a future need to increase considerably the output power within the limits of antenna voltage on these types of aerials.

For smaller aircraft, the power of the transmitter is governed by the available space, and a power 30-40 watts into the aerial system is the usual compromise.

Frequency Stability

The stability requirement of the Atlantic City regulations for airborne equipment is $\pm 0{\cdot}02$ per cent. This requirement makes the use of crystal control general. Until recently, crystal control was only applied to the transmitter, the receiver being continuously tuneable. In modern equipment, with the trend towards simplified operation, crystal control of the associated receiver is a normal feature.

Fig. 1. STR.18C 100 channel pilot's remote control unit

Number of Spot Frequences

The number of spot frequencies which should be offered is somewhat debatable. It is, however, generally accepted that, with 150 channels available, an aircraft can fly to any part of the world without the necessity of setting up new channels.

Remote Control

The equipment should be capable of being controlled from a small unit not exceeding 8in high, 6in wide, and 2½in deep. Changing of frequency should be carried out by the absolute minimum of controls. As mentioned previously, in present-day large aircraft it is generally necessary for control to be provided at two points. This can be done either by installing two remote-control units with a simple change-over arrangement, or by replacing one of the control units with a set of controls on the front panel of one of the main units with a similar change-over arrangement. (Fig. 1 shows a typical remote-control unit.)

Receiver

The performance of the receiver should be equivalent to that of a conventional high-grade communication receiver, i.e. having a sensitivity of the order of $2\mu V/m$ on C.W. with a signal-to-noise ratio of the order of 20db, the important difference between a modern airborne receiver and its ground counterpart being the economy in controls and provision for remote operation. Some modern receivers are fitted with a muting control which can be set to open at a pre-determined signal level. This feature is thought to be a very useful one for equipment operated by the pilot, since it removes unwanted noise in the headphones when a signal is not present. The facility is, however, of doubtful value in an operator-controlled equipment, since he may well miss signals which are not sufficiently strong to open the muting circuit.

Power Supply

The equipment should operate from the low-voltage power supply which is available in the aircraft. This is a nominal 27 volts D.C., which may vary between 22-29 volts under certain flight conditions. In new aircraft, however, this voltage is controlled over much narrower limits.

An equipment meeting a large number of the operational requirements indicated above is shown in Fig. 2. The equipment consists of five main units:—

(1) *The Receiver Drive Unit* (Extreme left-hand unit in Fig. 2) containing the receiver, the initial stages of the transmitter, and all the frequency-determining circuits for both the transmitter and receiver. From this unit the equipment can be set up on 100 spot frequencies without touching any other unit. Once these spot frequencies have been set up, the equipment can be operated either from controls on the unit or on R.T. only from a remote-control unit intended for operation by the pilot.

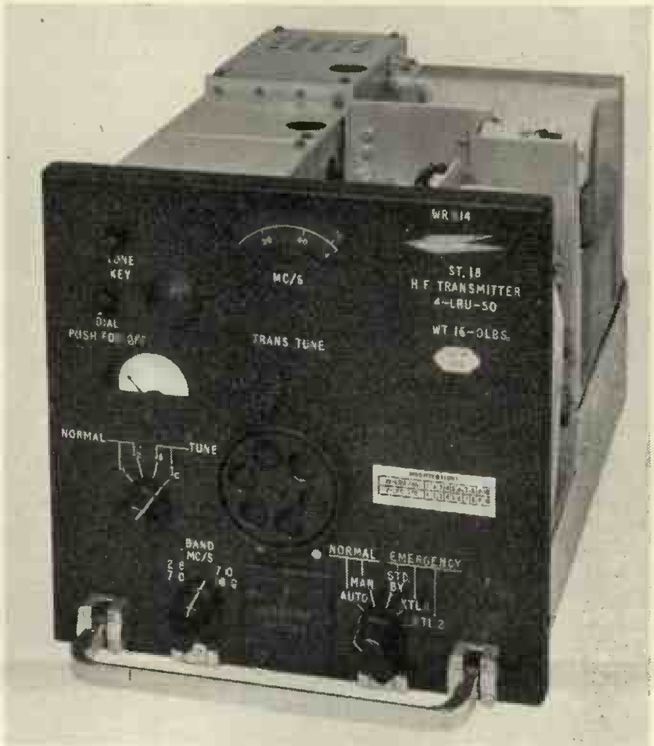
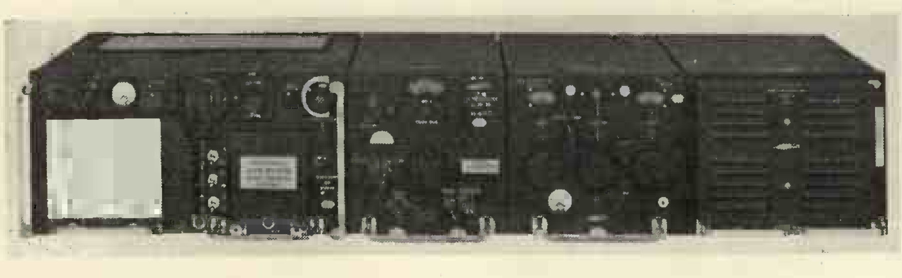


Fig 3. STR.18C 100W transmitter unit

(2) *The Transmitter Unit* (Fig. 3) containing the transmitter penultimate and output stages, terminating in a low impedance 70 ohm output. The transmitter is inductance-tuned by three variable inductors which are ganged together, thus simplifying the remote-control system and setting-up procedure. The output of the transmitter varies over the frequency band between 100-200 watts.

(3) *The Aerial Coupling* (Fig. 4) comprising a π-network of two variable inductors coupled by any one of six capacitors.

Fig. 2. STR 18C 100-channel H.F. airborne communication equipment



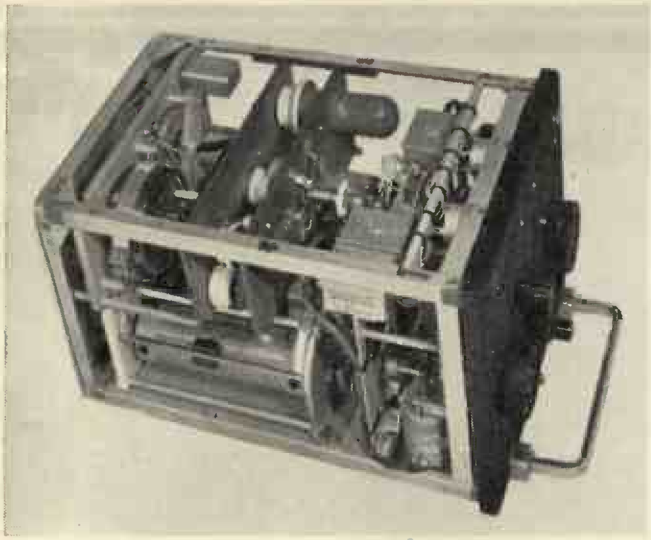


Fig. 4. STR.18C wire aerial coupling unit

(4) *The Power and Modulator Unit* (Fig. 5) containing a rotary transformer operating from 27 volts input, giving an output of 600 volts D.C. and 300 volts D.C., and a modulator capable of modulating the transmitter 100 per cent with some 10-15db of speech clipping.

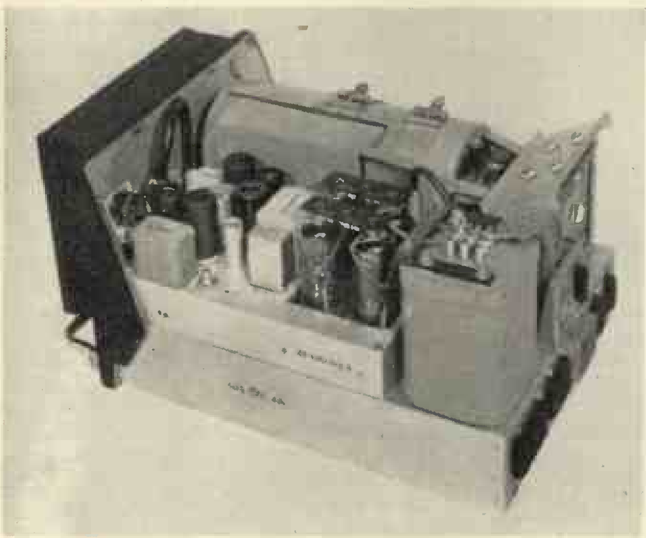
(5) *The Remote Control Unit* (Fig. 1) containing those controls required by the pilot to operate the equipment in the R.T. condition only.

An equipment such as that briefly described above represents the contemporary method of splitting airborne equipment into a number of units (an earlier version of the equipment went further and had a separate receiver and transmitter drive unit). Current American practice is to have the transmitter, receiver and modulator in one large unit without any external operational controls, with separate power unit and aerial tuning unit, the control unit being usually tailor-made to suit the aircraft. If two control positions are required, this is provided by two control units with a simple change-over switching device.

Future Trends

Future trends in H.F. airborne equipment come under three broad headings. The first must obviously be towards

Fig. 5. STR.18C power and modulator unit



an improvement in the "certainty rate" of establishing communication. Secondly, increasing the flexibility of the equipment so that an aircraft can operate in any part of the world and always have the necessary frequencies available. Thirdly, the most important of all, towards greater reliability of operation, the ultimate aim being that the equipment can be installed in an aircraft with the certain knowledge that it will go on operating satisfactorily for, say, 1 000 flying hours without further attention.

CERTAINTY OF COMMUNICATION

Reliability of communication can come from an increase in transmitter output power, and in the case of R.T. operation, improved or different systems of modulation. Considerations of weight and power requirements and the high aerial voltage involved make any increase in power above 300-400 watts impracticable in normal aircraft. Under average conditions, it is not likely that any great improvement will result from such an increase over the normal 100-150 watts. As far as improved methods of modulation are concerned, the use of single sideband is being investigated. Should any move in this direction be made on an international basis, considerable improvement in R.T. communication will result. Such improvements must, however, be weighed against the increased complexity of the equipment, particularly during the inevitable interim period when both single and double sideband equipment have to be carried. As an alternative, a good deal of work has been done on speech clipping which effectively increases the mean modulation depth. Results of tests on equipment with some 10-15db of clipping show a very marked increase of intelligibility in conditions of high noise level and/or weak signals.

FLEXIBILITY OF EQUIPMENT

The ultimate requirement is that an equipment shall have available every frequency which can be possibly ever required. This means that the equipment must be capable of transmitting and receiving a frequency every 0·5kc/s throughout the recognized air frequency bands. To provide this facility would, however, make an equipment extremely complex and expensive. Therefore, it would appear that alternative equipment should be available, one offering, say, 100 or 150 channels, utilizing one crystal per channel, the other offering every likely channel and employing some form of crystal-saving technique. To satisfy the above, it seems likely that future trends in the build-up of equipment will be a compromise between the British and American systems, with one unit containing the frequency-determining circuits, which would either be frequency-synthesizing or single-crystal-per-channel type, and a second unit containing all the other portions of the transmitter and receiver plus the modulator. The power unit and the aerial coupling unit would be separate units. With an arrangement such as this, an airline operator would carry a standard transmitter-receiver unit, and would have a choice of which type of frequency-determining unit he carries.

RELIABILITY

Work is constantly going on with a view to improving the reliability of equipment. The recent introduction of "ruggedized" valves will do a great deal towards removing the principal source of trouble in airborne equipment, i.e. early valve failure. The trend towards the use of A.C. in aircraft means that it will be possible to operate all motors in airborne equipment, i.e. tuning motors, fan motors, etc., from A.C. instead of D.C. This will result in a considerable increase in the reliability factor, due principally to the fact that no brush gear will be required. The use of A.C. will also make it possible to dispense with D.C. rotary convertors, and change over to static A.C. power packs. All these factors have a very considerable bearing on the overall reliability of the equipment.

Radio Teleprinter Systems

By D. H. C. Scholes*

A great and increasing proportion of the world's communications is carried by radio teleprinter systems, but the techniques involved have received little notice in the general technical press. It is the purpose of this article to review the various systems of automatic radio telegraphy and to discuss in general terms some of the technical problems involved. A commercially available receiver terminal using the latest development—F.S.K. is described. The principle of operation of the teleprinter is also briefly described because of the influence of the machine on the electronic techniques developed for the various systems.

THE field of automatic radio telegraphy can be roughly divided into two classes of operation—short distance circuits using ground-wave (where conditions approximate to those obtaining with physical circuits) and long distance operation. It is to this latter field that the major part of this article is devoted.

It is thought that some readers, while knowledgeable in the wider field of radio and electronics, may not be so familiar with the principles of automatic telegraphy and the liberty is taken of digressing briefly for their benefit before coming to the radio aspect.

In telegraphy the intelligence is conveyed in the form of a series of "characters" each corresponding uniquely to a particular letter, figure or sign. These characters are made up of two classes of signal designated "marks" and "spaces". These are indicated either by the transmission of signals of opposite polarity or by sending a signal for "mark" and none for "space." In the International Morse Code (Fig. 1), the spaces are not really used to convey intelligence, but to separate the characters and the two types of mark signal of which they are composed. These two signals are long and short "marks" the long one or "dash" being three times the length of the short or "dot". The spaces between the dots and dashes of a character are the same length as dots and those between characters are of equal duration to dashes. As the characters of the I.M.C. contain varying numbers of dots and dashes, they are of varying length.

The system used for teleprinter operation (Fig. 2) is rather different and is known as the "5-unit" code. Here again the characters are composed of spaces and marks, but in this case both play an equal part in conveying the intelligence. All the characters in the 5-unit code are of the same length: they consist of a "start" signal (space), five signals which may be any combination of marks and spaces and correspond to the letter to be sent, and a "stop" signal (mark). The transition from mark to space throughout the character is virtually instantaneous and each character therefore really consists of a continuous signal of varying polarity. Each mark or space of the character is 20 milliseconds in duration, except the stop signal which is 30.

The earliest method of radio communication was by manual telegraphy using Morse and in the hands of skilled operators this method can still provide more reliable communication under adverse conditions than any other. Even with skilled operators, however, speeds higher than 30 to 40 words per minute cannot be maintained and with only moderate skill, the speed falls to 20 W.P.M. or less.

The automatic morse system, where the transmitter is keyed by a paper tape with punched coding and the signal is received on a similar tape travelling under an electromagnetically operated pen, has been successfully applied to radio telegraphy with the object of eliminating the skilled telegraphist and speeds up to 600 W.P.M. are possible. This system is still in wide use, but for many classes of traffic (such as aircraft movement messages) where there must be the minimum delay between the origination and receipt of messages and the transmission must be undertaken by personnel whose skill does not lie in the direction of morse telegraphy, the auto morse system, involving transcription of the received message from morse characters on a tape has obvious limitations.

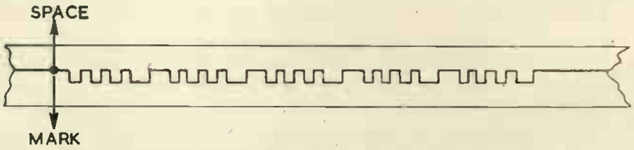


Fig. 1. Typical morse signal on auto-morse receiving tape

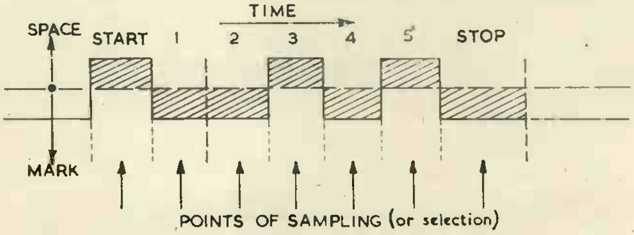


Fig. 2. Typical teleprinter signal

It is here that the teleprinter comes into its own. Sending is within the power of anyone who can work a typewriter and receipt is direct on a printed page. Carbon copies can be prepared simultaneously and in addition the signal can be regenerated for re-transmission over radio or wire at the initial (or any subsequent) receiving station. For receiving the signal, no skill is required at all—the teleprinter will continue to receive automatically as long as it is fed with paper and ribbon. As the paper is in long rolls rather than sheets, the machine needs quite infrequent replenishment. The normal teleprinter is limited by certain factors in its design to a maximum speed of 66 W.P.M. which is, however, quite adequate for most purposes.

As the problems of radio teleprinter operation are intimately bound up with the limitations and methods of operation of the teleprinter, a further short digression is necessary here for consideration of these factors. The operation of any key of the sending machine causes the "start" space to be sent followed by the 5 code units

* *The Plessey Company Ltd.*

corresponding to the letter, with the "stop" mark signal completing the operation. These signals are sent out at a rate which is controlled by a governed electric motor on the machine. At the receiving end, the start signal connects to a similar motor (governed to run at a speed within ½ per cent of the sender motor) a sampling mechanism which applies itself to the incoming signal at a time corresponding to the middle of each code unit with the object of determining whether that unit is a mark or a space. It will be obvious that the virtual identity of speed of sending and receiving motors is essential to ensure that the sampling is done correctly. It is only necessary to ensure synchronization holding for the duration of one character as the sending and receiving mechanisms are always *started* in step by the start signal.

A moment's consideration will show that any interference by the transmission medium with the time of arrival of the signal elements may combine with errors in the timing of the sampling to cause the receiving mechanism to interrogate at a time after the start signal which should correspond to the centre of a particular element but at which time the element in question has either not arrived or has terminated.

Other sources of similar error are rounding of the pulses (causing the receiving relay to be in the correct position for less than the allocated 20 milliseconds and thus reducing the margin allowed for error in the moment of sampling) and excessive sharpening of the pulses which may result in their containing too little energy to drive the receiving relay to its correct position. The vagaries of radio propagation over long distances are capable of producing all these effects and it is to their mitigation that the techniques used in radio-teleprinter operation are mainly devoted.

Finally, teleprinters can be used on either "single current" or "double current" working. The receiving relay is of the polarized type and if so adjusted, that there is no particular restoring force to either the mark or space position, it can be driven in either direction by the sending of signals of appropriate polarity by the transmitting machine. In single current working the sending machine applies a voltage to the line for mark and none for space. In this mode of operation the receiving relay is biased by applying a voltage of suitable polarity to hold it to space when there is no voltage on the line. This bias voltage is made equal to half the signal voltage to give symmetry of operation. When a sending machine is running but not sending it applies a continuous mark signal to the line. In double current working, a negative polarity corresponds to mark and positive to space. Teleprinters are so designed that reception of mark for a given length of time will switch off the receiving motor automatically and the reception subsequently of a calling signal will cause the motor to restart.

The main methods of conveying teleprinter signals by radio are:—

1. On-off keying of the carrier.
2. Radiation of different carrier frequencies for mark and space.
3. On-off keying of a single audio modulating tone.
4. Modulation at two different audio frequencies for mark and space.

Systems 2, 3 and 4 are known as frequency shift, single tone and two tone respectively. Systems 1 and 2 are normally restricted to H.F. working, while the others can be applied either to H.F. or to short range working on V.H.F. or U.H.F.

In all these systems the received signal is either already in the form of an audio tone or is converted into such a form by a heterodyne system. This enables the signal to be passed through narrow audio filters to improve the noise factor. Because of the use of this method, the C.W. on-off and F.S. systems are not suitable for V.H.F. and U.H.F. working. The direct relation between carrier frequency and audio note inherent in the heterodyne method would mean such wide variations of note frequency with carriers of any reasonably attainable stability that the filters would have to be so wide to avoid rejecting the signal that they would contribute nothing to the noise factor of the system. Single and two-tone working, where the note stability is dependent only on the stability of the generating oscillator, are more practicable for V.H.F. and U.H.F., but they have definite drawbacks for H.F. as will be shown later.

Single and two-tone teleprinter signals can, of course, be transmitted over any link which will accept audio modulation and are consequently applicable to A.M., F.M. or pulse systems. In addition with these systems, any appropriate method of line telephone channelling can be applied to radio links of suitable bandwidth to provide multi-channel teleprinter operation over one R.F. circuit.

Coming now to the main subject of long distance working, consider the case of C.W. on-off transmission. This corresponds roughly to single current working in that the two states are "signal" and "no signal" and consequently "bias" must be introduced at the receiving end. This immediately introduces a problem in that the bias has to have a value as near as possible to half the mark signal level. The use of fixed bias as on wire circuits is obviously not appropriate in the conditions of wide variation of signal level experienced on the H.F. band. This drawback would not be so serious if the received signal were composed of rectangular pulses, but in practice the edges of the pulses slope to a greater or lesser extent and this slope can be both great and variable. A little consideration will show that the application of fixed bias to a sloping pulse edge will have the effect of shortening the mark pulse relative to the space or vice versa according to the relation at the time between signal and bias levels. In bad cases, it could, of course, lead to the complete suppression of mark or space signals. This, as shown earlier, will cause wrong sampling and consequent misprinting.

At first sight it might appear that the use of A.G.C. together with automatic bias-level adjustment would completely cure this fault, but it will be seen that as some characters can consist of all or nearly all space pulses the time-constants of both A.G.C. and bias control circuits must be long enough to hold steady during such a character. Under these conditions, very rapid fading, which is quite common, will not be compensated, parts of a character will still suffer distortion and misprinting will frequently occur. It will thus be seen that C.W. on-off keying has its limitations. The use of dual or preferably triple-diversity reception is essential if reliable long distance communication is to be approached by this system as this method gives the best protection against rapid fading in the absence of any material help from A.G.C. Also diversity reception is indicated to combat deep fades which may take the signal below noise level at any particular aerial site, in which circumstances A.G.C. will, of course, be of no avail.

Both the on-off system and frequency-shift present the same problems in connexion with transmitter stability and receiver frequency-change and beat-frequency oscillator stability when very narrow audio filters are used because of the danger already alluded to of the tone frequency wandering outside the filter pass-band. It is common practice now to use temperature controlled crystals for all oscillators. The somewhat lower stability needed for the B.F.O. does, however, enable a variable free oscillator to be used to enable adjustment of the note to filter centre-frequency to be made in setting up a circuit.

In the on-off system the audio note is passed through a filter as already described and is then rectified and applied through a relay or valve keyer to the receiving teleprinter The filter must not be so narrow that it appreciably rounds the signals and for normal teleprinter signals a bandwidth of 100c/s seems to be the optimum. Care must also be taken in the design to see that the filter does not ring at the keying speed used. Because of the use of bias the effective signal power in this system of working is only half that corresponding to the signal at the receiver aerial.

Single-tone working with a conventional A.M. transmitter on H.F. suffers in the main from the same drawbacks as C.W. on-off. However, the carrier is now present all the time and this enables the A.G.C. and bias level problems to be simplified as these circuits can now have fast time-constants. The transmitter conditions, however, are now much more severe than for telegraphy as the carrier must be on all the time. As the modulation is keyed the operation does not quite impose a continuous 100 per cent modulated condition as well, but as the intelligence is now conveyed only by the sidebands, modulation level must be kept as high as possible. In order to compare the service likely to be afforded by this system with that by a C.W. on-off circuit, consider a transmitter having a power output at 100 per cent modulation the same as the carrier power of the C.W. transmitter. The power available for conveying the signal, residing in the sidebands only, is half this and, in fact, the comparison is rather worse in that it is only the power in *one* sideband which contributes to the noise factor of the system. In single tone working as in on-off C.W. the use of bias further reduces the effective signal. From the foregoing account, it will be appreciated that single tone is not really suitable for H.F. working. On V.H.F. with F.M. apparatus, of course, most of the objections connected with modulation are overcome, but we are still left with a single current system with its attendant reduction in effective signal strength.

Passing to two-tone working, we now consider a double-current system for the first time. In this case there are signals corresponding to both mark and space, the receiving relay is positively driven in both directions and no bias is needed. This has the two-fold effect of removing the need both for automatic bias adjustment and for wasting half the signal in overcoming the bias. The presence of a continuous audio signal (remembering that the transition from mark to space is virtually instantaneous) enables a limiter to be used in the two-tone receiving system with resulting improvement in constancy of signal level and possibly some improvement in noise factor. In the case of H.F. working, two-tone clearly has advantages over the systems already discussed and is, in fact, widely used. The conditions as far as the transmitter is concerned are, however, the most severe of all, corresponding as they do in continuous send with continuous 100 per cent modulation. On V.H.F., F.M. systems this trouble does not arise and two-tone affords the most satisfactory operation. Even with A.M. systems on V.H.F the problem is not serious as the transmitter power is in any case quite small and any but the most parsimoniously designed transmitter is generally capable of continuous operation.

The objection to the waste of the carrier power which applies to both the tone systems on H.F. can be met by the use of two tone on single sideband but a few moment's consideration will show that this is virtually a frequency shift system.

It is worth remembering again at this stage that the tone systems do not call for any special precautions in connexion with frequency stability of the R.F. circuit and consequently they require less specialized radio systems provided a few simple precautions are observed. The frequency shift method, which will be considered next, does require both special transmitting and receiving apparatus to ensure the best results. The results do, however, appear to justify the extra complication.

Frequency shift operation is one of the more recent developments in radio teleprinter working and is really an F.M. system, although the signal is conveyed by the amplitude of the frequency deviation rather than the frequency at which the deviation takes place.

In this system one carrier frequency corresponds to "mark" and another, a few hundred cycles different, to "space". Experience has shown so far that the change between mark and space should be arranged through the smooth alteration in the frequency of one driving oscillator rather than an abrupt change of drive from one oscillator to another on a different frequency. It will be seen that F.S.K. is a double current system like two-tone, but that it has the added advantage of being a C.W. system which enables all the power radiated by the transmitter to be usefully employed. It has, in addition, the advantage over the other C.W. system that the carrier is always present for control of A.G.C. Limiters can be used, as in the case of two-tone.

Comparing the F.S.K. system with the C.W. and two-tone systems it is found:

1. Versus C.W. on-off it has the advantage of coherent carrier and double-current working. By addition of a drive unit F.S.K. can be applied to an existing telegraph transmitter (al hough this may need derating to allow for the new continuous key-down condition). Use of F.S.K. will also probably result in lower distortion of the signal elements than in the case of on-off keying (which is usually done at low level and subjected to considerable distortion by subsequent class-C amplifiers). At the receiving end, a substantial quantity of extra equipment will be needed, although if the on-off system employs stable frequency-change and beat-frequency oscillators, these will serve equally well for F.S.K.

2. Versus two-tone it has the advantage of a C.W. system of wasting no power in a carrier which conveys no intelligence. The conversion of an on-off transmitter to two-tone is also virtually impossible except by the addition of an expensive high power modulator. In this case also, the C.W. transmitter would have to be derated to allow of continuous key-down with the added stringency of a continuous 100 per cent modulated condition as well.

   Practical tests have also shown that F.S.K. appears to show marked advantages in the presence of selective fading and that dual diversity with F.S.K. gives as great an improvement as triple with other systems.

The system has several technical difficulties and of these the major one is the need for exact agreement between the mean point of the transmitted mark and space frequencies and the receiver oscillators. Automatic frequency-control of the receiver can be used but this is subject to the severe limitation of danger of capture by unwanted interfering signals in the congested H.F. band. The need for this high degree of synchronization arises from the fact that any shift of the centre-frequency will have a first-order effect on the mark-space ratio and a small drift will cause serious telegraph bias distortion. In the case of on-off keying small frequency drifts will only cause changes in amplitude whose effect will be of the second order only on bias distortion provided auto bias control is used. This factor in the case of F.S.K. is more of a technical problem than a system defect and the use of very stable oscillators throughout gives a complete and quite practical solution.

In F.S.K. reception, the final extraction of the teleprinter signals can be achieved either by the use of a B.F.O. at I.F. with subsequent resolution of the mark and space elements by two audio filters or a discriminator or, by converting the signal to a low I.F. frequency such as 20kc/s and using a discriminator at I.F. frequency. The relative advantages of filter versus discriminator methods are the subject of much controversy, especially in respect of which system is more tolerant of centre-frequency drift of the signal. The discriminator does appear to have the advantage that no limitation arising from filter ringing is placed on signalling speed.

The discriminator system will also accept a wider range of "shifts" (mark-space frequency spacings) and is, therefore, more flexible but this can be paralleled in the filter system by the use of switched or plug-in filters. Filters would appear to be rather more satisfactory in the mitigation of the effects of noise.

A table is given below showing very roughly the relative effectiveness of the various systems discussed for use on long-range H.F. circuits. The figures represent equivalent radiated power necessary for the same degree of circuit reliability. Auto-morse and telephony are also included for comparison. It is realized that the relation can never really be as simple as shown because of the large number

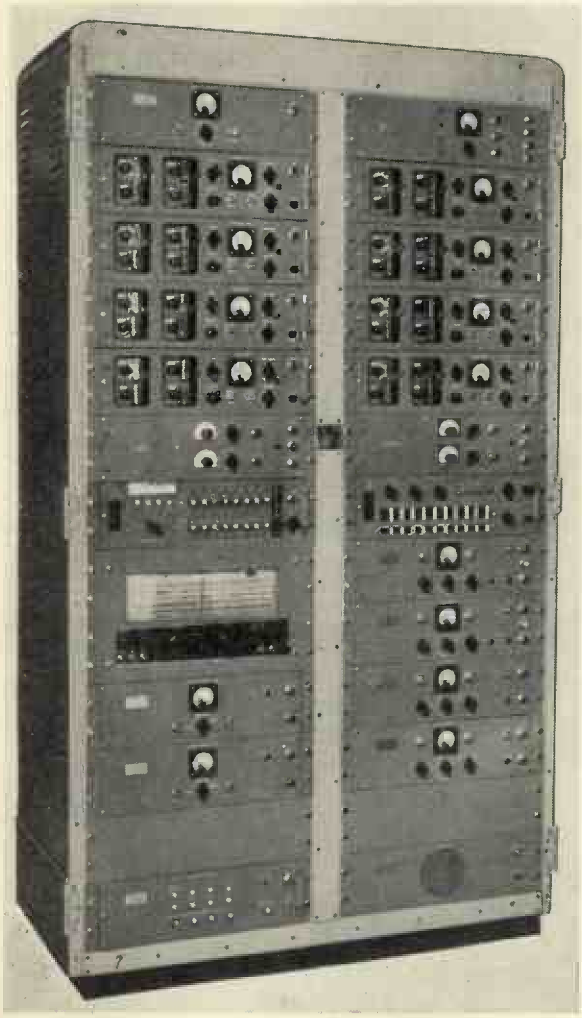


Fig. 3. Four channel dual diversity F.S.K. receiver (Plessey)

of factors contributing to the "goodness" of the circuit but it is thought that this simple comparison, based, as it is, on considerable field work over a number of years will be of some slight value.

Manual Morse (C.W.)	0db
T.P., F.S.K.	+ 7db
Auto Morse (C.W.)	+ 10db
T.P. two-tone	+ 10db
Voice (A.M. 100 per cent mod.)	+ 14db
T.P. single tone	+ 16db

NOTE: No data on 2-tone S.S.B. but probably about the same as F.S.K.

In conclusion, it seems appropriate to describe briefly a frequency-shift receiving system as representative of the latest system of radio teleprinter operation in regular service. It is worthy of note in passing that on the operational side, systems are being introduced which will enable the automatic routing of teleprinter messages to different destinations by the use of switching devices at the main receiving terminals actuated by code groups prefixing the messages.

The equipment to be described, which is illustrated in Fig. 3 provides four separate dual-diversity channels, any two of which may be used on traffic simultaneously.

The eight receivers are fed from two aerial systems via a multi-channel aerial amplifier having two independent amplifier channels, each with 5 outputs.

A high frequency oscillator unit, employing closely temperature controlled crystals, provides four independent outputs for the four receiver pairs.

Similarly, two beat-frequency oscillators units provide four independent crystal controlled outputs. These units also embody highly stable free oscillators which can be used as alternatives to the crystals if extra flexibility is required.

Diversity switching and mark and space element separation is accomplished on each diversity channel by a convertor unit. The convertor units are of specialized design and completely suppress the receiver which is at any instant producing the poorer signal. The rapidity and effectiveness of this action is such that change-over can take place during a signal element without introducing unacceptable distortion. The convertor units also contain the limiters and mark and space filters and rectifiers needed to produce the D.C. signals for teleprinter operation.

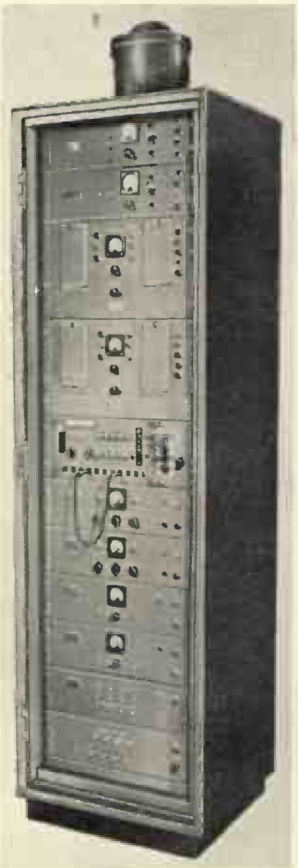


Fig. 4. Eight channel F.S.K. transmitter drive unit (Plessey)

The low level D.C. produced by the convertors is passed to the keyer amplifiers which produce the higher level polar D.C. which finally operates the teleprinters. The keyer amplifiers also embody "mark-hold" circuits which produce a continuous marking signal to close down the teleprinters should the radio signal fail. Restoration of a proper signal automatically restarts the system.

Restriction of space has inevitably led to a rather sketchy treatment of this complex subject, but it is hoped that this brief survey will prove of interest to those readers who are not familiar with the rather specialized and little publicized field of radio telegraphy on which a great proportion of the world's communications depend.

Acknowledgments

The writer wishes to thank the Plessey Company for permission to publish this article and illustrations.

Developments in Frequency Shift Keying and Radio Teleprinter Systems

By A. G. Williamson*, A.M.I.E.E.

In the mechanization of telegraphic communications, equipment must be promoted which has a lower error liability than that of the operator. Causes of errors due to printing machines and radio path effects are examined and field test comparisons between various forms of diversity transmission are quoted. The degree of sideband emission in F.S.K. *systems is mentioned and several types of transmitting and receiving equipments briefly described. The importance of the type of telegraph code used is stressed and various printing mechanisms described.*

THE reasons for the choice of the 2-30Mc/s band for long distance radio telegraph links and the attendant necessity for changes of frequency at intervals of some hours and at much longer intervals, are well known. Despite all efforts, there are still periods when no traffic can be passed and this means that the maximum possible use must be made of the circuits when conditions permit.

The Armed Services use the same range of frequencies for long and short distance links and in the latter case, in addition to propagation problems, there are those set by aerials which cannot be most efficiently sited and possibly by interference from other stations.

Developments in radio telegraph systems have been directed towards passing the maximum amount of intelligence in the minimum time for the maximum number of hours per day, using the minimum bandwidth and transmitter power required for reliable service.

Reliability in this context refers to improving on the performance of a highly efficient human operator who makes one error in 10 000 characters[1]. Thanks to the vagaries of the ether, the error rate in as many characters on a normally good long distance H.F. link averages as much as 15 and depending on the type of code used, can lead to as many as 10 undetectable errors[2].

The available bandwidth may be used for a single high speed keying channel or divided in time or frequency into a number of low speed channels. However the circuit bandwidth is used, machine transmission of the intelligence is inevitable, thereby introducing the problem of ensuring that the signal received is not so distorted in the time dimension that the receiving machine cannot translate it correctly.

Telegraph Distortion

The effect of one form of telegraph distortion on the teleprinter (British) and teletypewriter (American) will be considered. The same 5-unit start-stop code in a slightly different form is used in each case. In the British system, the signals for each character consist of a positive start signal of 20msec, followed by five signal elements, each of 20msec, and a negative stop signal of 30msec. As the shortest element is 20msec in duration, the keying speed is 50 bauds corresponding to a keying frequency of 25c/s.

On receipt of a start signal, the receiving equipment is rendered active for 130msec and then is passive until the next start signal arrives, thus avoiding the necessity for ensuring synchronization between sending and receiving mechanisms over long periods. The actual process by which the printer sets up to print the character is carried out in an interval of 6msec in the centre of the 20msec element interval.

Transmission systems can cause distortion which is defined as the time by which any change-over is early or late with respect to its correct position as measured from the onset, expressed as a percentage of unit code element length.

In Fig. 1 is shown the code for "S" and it will be

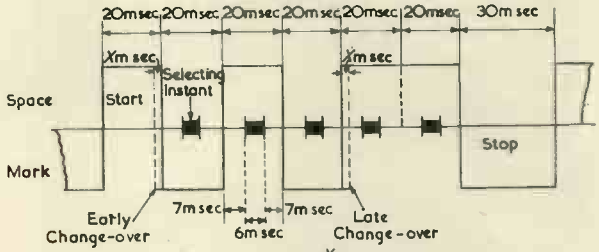


Fig. 1. Teleprinter code for letter S

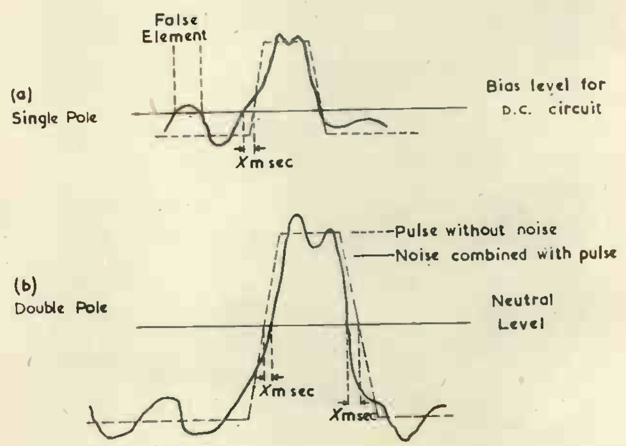


Fig. 2. Effects of severe noise on signal after demodulation

apparent that, provided the desired change-over occurs between two selection intervals, the correct character will be printed. Thus the maximum distortion which a teleprinter will tolerate is 35 per cent, but this assumes perfect adjustment of the receiving mechanism and for safety, a figure of 25 to 30 per cent should be taken as the limit.

Similar considerations apply in the case of the automatic high speed (100 baud) receiving equipment although the permissible distortion is more than 80 per cent.

Radio Path Effects Causing Telegraph Distortion

NOISE

The effects of noise on a signal after demodulation at a receiver are shown in Fig. 2 for single and double pole signals. It will be seen that noise can cause false signals

* *Formerly Redifon Ltd.*

and/or telegraph distortion in a single pole signal and telegraph distortion in a double pole signal.

FADING

Fading of all frequencies of the signal in unison (flat fading) can result in low signal-to-noise ratios and where very narrow bands of frequencies fade independently telegraph distortion may occur.

MULTI-PATH EFFECTS

Though the signal may be launched so that there should only be one path between transmitting and receiving aerials, variations in the reflecting layers will give rise to other and slightly longer paths.

For 3 000 mile links two and even three path conditions are common, but for shorter distance working, two path conditions will be more general. The maximum group time delay regularly encountered on 3 000 mile links are of 2msec duration, but at the low frequency end of the H.F. band greater delays may be encountered[4].

Other Causes of Telegraph Distortion

Apart from distortion of elements and groups of elements in the radio path, the shape of the element can vary due to changes in wave shaping circuits, and changes in oscillator frequencies, at transmitter and receiver.

Methods of Overcoming Fading and Multi Path-Effects

In using A.G.C. on radio telegraph receivers, difficulties are encountered when the speed of the fade enters the range of possible signalling speeds as can occur under multi-path conditions.

To counteract these conditions use must be made of schemes using a number of receiving aerials—space diversity; or simultaneously transmitting a number of frequencies for each signal element—frequency diversity; or using a radio channel having a good performance in the presence of multi-path fading effects—single sideband systems. Use of two or three of these methods together is common, but there are factors governing the choice of combinations. For example, long distance commercial links may use receiving stations carefully chosen and of considerable area, whereas Services stations may be mobile, ship-borne or otherwise restricted in area. Where space diversity is possible, two or three aerials spaced 5 or more wavelengths apart feed separate receivers.

The gain of double over single and treble over double diversity, depends to a large extent on the complexity of the aerials employed. For example, in the case of simple aerials, a gain of 10db for triple over double is claimed[3], while for complex aerials the difference may only be a few decibels[4]. In comparing results the method of combining the outputs of the receivers should be considered.

Frequency Diversity

This may be divided as follows:

1. Transmitter diversity.
2. Frequency shift keying.
3. Phase modulated C.W. on-off.
4. 2, 4 and 6 tone A.M.

It is very difficult to compare the efficiency of these systems as their performance is affected by signal-to-noise ratio, speed of signalling, permissible distortion, details of receiver circuit, frequency deviation used, frequency stability of link and whether square or rounded signal is transmitted.

TRANSMITTER DIVERSITY

This has been tested by RCA[5] by using two 1kW transmitters at 15·49Mc/s at Bolinas, California, feeding two separate rhombic aerials eight wavelengths apart. The transmitters used frequencies differing by 200c/s and were keyed at 30 bauds 850c/s shift. Identical filter type receivers with I.F. bandwidth response 5db down at 900c/s were installed at three urban sites in New York and received transmissions from one and then two transmitters alternately at 5-minute intervals. The results of these tests are shown below.

SITE	S/N RATIO IN 1·7KC/S BAND db	ERRORS WITH 1 TRANSMITTER	ERRORS WITH 2 TRANSMITTERS	NO. OF CHARACTERS TRANSMITTED	RATIO OF IMPROVEMENT
1	−5 to −16	201	13	10^4	15·5 : 1
2	+6 to − 6	409	25	$4·5\times10^4$	16·3 : 1
3	+9 to 0	65	2	8×10^3	32 : 1

FREQUENCY SHIFT KEYING

In the purest form the keying is so applied to a single oscillator that the shift between the mark and space frequencies is smooth and in this case the signal may be regarded as a frequency modulated carrier, the deviation being the shift and the keying speed the modulation. Typical values are 50 baud (25c/s) working and deviation of from 148-560c/s the lowest and highest shifts recommended by the C.C.I.R. A more complex condition results when the shift in frequency is obtained by switching between two R.F. oscillators. Difficulty is experienced due to transients arising from the sudden phase discontinuities caused by the switching, and though filtering may be used the overall result is a system of higher inherent distortion.

For telegraph channels on which fading is experienced the bandwidth permissible for A1 (C.W. on-off) is five times baud speed of keying, for F1 (F.S.K.) this is increased by the amount of frequency shift (I.T.U. Atlantic City 1947). While it may be difficult to meet this condition in an A1 transmitter, in F.S. working the sideband radiation is more easily regulated. If the modulation index, i.e. ratio of half total shift to keying frequency, is less than 0·5 there will be two significant sidebands, i.e. greater than −40db below unmodulated carrier, and the bandwidth for sine wave keying will be four times keying frequency. As the modulation index is increased the sidebands of greatest energy move away from the centre frequency and by using a keying wave containing fundamental and harmonic at one-third of the amplitude of fundamental instead of fundamental only, the strongest sidebands may be moved further from the centre frequency, but at the expense of a slight increase in bandwidth[6,7,8].

For example:

WITH 50 BAUD KEYING, 450C/S SHIFT

Fundamental only:

Modulation index 225/25 = 9
Therefore number of significant sidebands = 13
Total band 26 × 25 = 650c/s
Strongest sidebands at ± 100 and ±125c/s

Fundamental plus third harmonic at $\frac{1}{3}$rd amplitude

Modulation index 225/(25 × 1·5) = 6
Therefore number of significant sidebands = 9
Total band 18 × 37·5 = 675c/s
Strongest sidebands at ± 187·5 and ± 225·0c/s

These figures may be compared with the total band of 450c/s occupied by a 150c/s channel keyed at 100 bauds with fundamental and third harmonic.

At the receiver the advantages of F.S.K. are that a signal amplitude is transmitted continuously allowing the A.G.C. to be more effective and limiters having a range of some 60db and acting in 1msec may be used. The limiter not only removes amplitude variations due to flat fading, but can be used in space diversity systems to discriminate between the signal levels in two paths.

Field tests conducted by Cable and Wireless Ltd on the London-Ascension circuit[1] showed that the use of F.S.K.

gave an advantage of 10db over c.w. on-off using a single receiver and an elementary receiving aerial. In field tests conducted by RCA[9], F.S.K. on dual diversity reception using gated I.F. combination gave a gain of approximately 11db over c.w. on-off on triple diversity reception, at an error rate of 0·1-0·5 per cent.

A theoretical analysis[10] of the advantages of various receiving arrangements for on-off and F.S.K. signals of the same keying speed, passing through an I.F. amplifier of the same bandwidth in each case, gave the following in terms of threshold signals:

RELATIVE SIGNAL-TO-NOISE RATIOS			
C.W. on-off	C.W. on-off followed by 125c/s filter	F.S.K. filter detector followed by 250c/s filter	F.S.K. discriminator followed by 125c/s filter
0db	-6·8db	-9·8db	-14db

PHASE MODULATED C.W. ON-OFF

When the radiated pulse of R.F. is phase modulated by about one radian, the following sideband distributions occur:

Ratios relative to unmodulated carrier = 1.					
Radian	0·5	0·75	1·0	1·4	1·5
Carrier	0·94	0·86	0·76	0·57	0·54
1st S.B.	0·24	0·34	0·44	0·54	0·56
2nd S.B.	0·03	0·06	0·11	0·20	0·22
3rd S.B.	0·005	0·01	0·02	0·05	0·06

The rate of modulation should be at least several times the keying frequency and thus with high speed keying, the use of a modulation angle greater than 1·0 would cause significant third harmonic sideband occupying a wide band.

When received on an A.M. receiver, this type of modulation has, in some instances, proved as good as F.S.K. even on a link on which C.W. fading ratios of 30 to 40db were observed. It is interesting to note that in field trials[11] this superimposed phase modulation was applied to F.S.K. and gave a 50 per cent improvement over a period when the error rate was 1 to 2 per cent and for short intervals the reduction was greater. Obviously, this phase modulation applied to F.S.K. results in a transmission which occupies a prohibitively wide frequency band.

2, 4 OR 6 TONE A.M.

On Double Sideband Transmitters

It may be said that the direct application to radio of wire line type voice frequency telegraph systems with a view to availability of equipment and compatibility started a development, results of which seriously challenge F.S.K. systems. Two-tone experiments led to the use of four-tone, two tones per element. This was extravagant in transmitted bandwidth and hence the application to S.S.B. systems followed.

On Single Sideband Transmitters

Systems employing a separate A.F. tone for each element (two-tone) when applied to the carrier of a S.S.B. transmitter give an emission fundamentally identical with that given by keying two R.F. oscillators whose frequencies correspond to those of the sidebands. A general advantage of S.S.B. systems is that the carrier can be reconditioned at the receiver and used with a simpler A.F.C. than is possible with a F.S.K. transmitter. Most S.S.B. systems carry at least one speech channel and extra two-tone channels are added at A.F. where required. Frequency stability (± 3 per cent of shift) between channels is more easily obtained than if R.F. two-tone channels were to be added.

The difficulties of effecting comparisons between various systems have been mentioned, but a very useful approach is made by use of the Post Office fading machine or "artificial ether"[12]. In this equipment overall fading and selective fading and multi-path effects with steady or varying noise can be studied.

The following comparisons were made at a signalling speed of 50 bauds with a simulated two-path transmission.

Approximate Order of Merit in Terms of Telegraph Distortion in the Presence of Selective Fading

ORDER OF MERIT	FREQUENCY-SHIFT OR TWO-TONE	FREQUENCY CHANGE c/s	SQUARE OR ROUNDED SIGNALS	METHOD OF RECEPTION*
1	FS	850	S	FL
	TT	850	S	FL
2	TT	840	S	A
	TT	600	S	AL
	TT	600	R	AL
3	FS	120	†	FL
4	TT	120	R	AL
5	TT	120	R	A
6	TT	840	R	A

* A = Two-filters-AM. detector. AL = Limiter-Two-filters-AM. detector.
FL = Limiter-linear discriminator. † Total bandwith 200c/s at 6db.

These tests do not simulate S.S.B. transmission and hence the following field tests made by Cable and Wireless do not seriously compromise the P.O. results. In the Cable and Wireless tests a system was used in which two S.S.B. systems with opposite sidebands suppressed share the same carrier frequency. On one sideband were three F.S.K. channels of 150c/s shift and on the other a two-tone system using 680c/s and 780c/s.

With a signalling speed of 50 bauds, the average number of times in the two minute period that the telegraph distortion exceeded 12½ per cent on the two-tone channel was six times that on F.S.K. when using a single receiver. When using double diversity the F.S.K. was 18 times better. An interesting feature of these tests was that on double spaced diversity, 100 baud working, for a figure of 10 per cent distortion in the two minute period, reception on F.S.K. receivers was four times better than when the S.S.B. receivers were used.

Frequency Shift Keying Transmitters

These are standard in amplifier and power stages, but the frequency determining stages differ as the frequency tolerances applicable to fixed transmitters are 0·003 per cent for the carrier and ± 3 per cent on the frequency shift itself. In practice greater stability is desirable.

PULLED MASTER OSCILLATOR TYPE (Fig. 3)

A keying valve is used to shift the frequency of the oscillator and if this valve is a cathode-follower placing an inductance in series with a crystal, a satisfactory performance results[2a].

PULLED *LC* OSCILLATOR AND FREQUENCY CHANGER TYPE (Fig. 4)

The auxiliary oscillator is centred on 200kc/s and the master oscillator frequency chosen to suit the channel in use. As it is not possible to shift the frequency of a 200kc/s crystal oscillator sufficiently, this oscillator must be an *LC* type.

PULLED CRYSTAL OSCILLATOR AND FREQUENCY CHANGER TYPE (Fig. 5)

The Redifon GK85 unit is of this type and by using pulled crystals and a frequency changer, gives a higher frequency stability than an *LC* oscillator type. This arrangement also permits flexibility in the degree of shift and the sense of the shift with respect to the carrier frequency.

Frequency Shift Receiving Equipment

The receivers are very similar to high quality communication receivers in the early stages, but the stability of oscillators, R.F. and I.F. stages must be very good. Alternatively, any drift in these circuits must be corrected by an A.F.C. system or compensation provided for these effects. By using adaptors, existing communication type receivers can be effective in F.S.K. links.

Receiving Equipment for Single Aerial Reception

1. *Filter Type Receiving Adaptor* (Fig. 6)

The final I.F. output is heterodyned with an A.F.C. controlled B.F.O. and the output fed through a limiter to four narrow-band filters. Two of these select the code elements while the other two, spaced about 1 element by the permissible drift frequency, provide the A.F.C control.

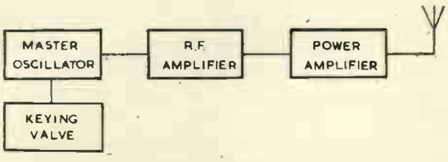


Fig. 3. Pulled master oscillator

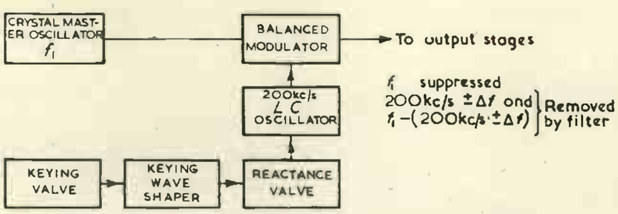


Fig. 4. Pulled LC oscillator and frequency changer

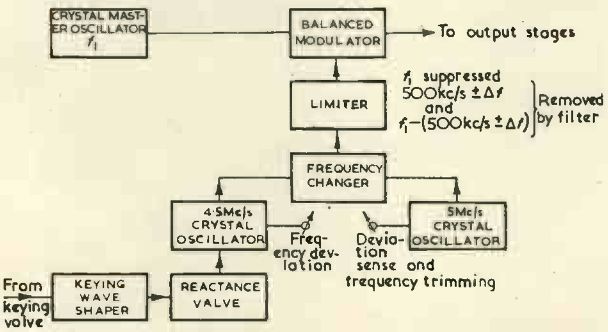


Fig. 5. Pulled crystal oscillator and frequency changer

Discriminator Type Adaptor (Fig. 7)

The adaptor unit, developed by Redifon Limited in conjunction with the Ministry of Supply, incorporates an alternative method of drift compensation. The input circuits double the I.F. as a safeguard against instability and feed a two-stage limiting amplifier. A noise suppressing (squelch) bias may be applied to the second limiter. When the level of the input signal is sufficiently high, this bias may be set to suppress any noise output which would arise if the transmitter shut down. The Foster-Seeley discriminator is followed by a low-pass filter restricting the noise bandwidth passed on to the D.C. amplifier. Any appreciable drift of the transmitter and receiver oscillators will give rise to an asymmetrical output from the discriminator and D.C. feedback is provided which restores the symmetry as long as the drift does not exceed ± 2·75kc/s. The shape of the elements is improved by passing them through a slicer which squares

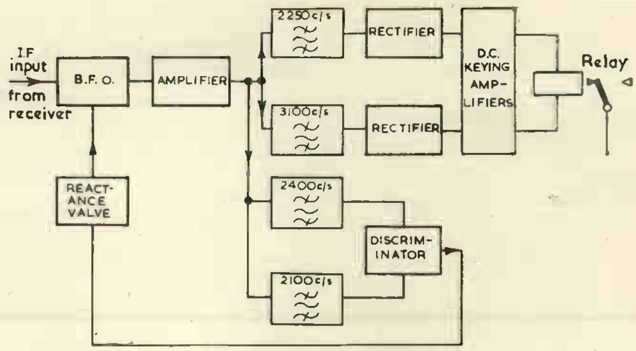


Fig. 6. Filter type receiving adaptor

the positive and negative crests. By this means the telegraph distortion is better than ± 2 per cent provided that the receiver and receiving relays are correctly set up.

A discriminator type adaptor and power supply unit

Receiving Equipment for Spaced Diversity Reception

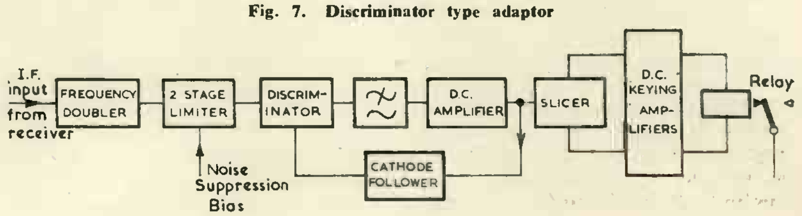
Combination Following Comparison of Signals after Discriminator (Fig. 8)

The Redifon R151 receiver in conjunction with B.T.R. type F.S.Y.1. adaptor provides a flexible high performance receiving equipment. The receiver is highly stable and has six switched channels. Each channel is provided by plug-in units for R.F. and buffer circuits to suit the first crystal oscillator frequency. This oscillator may be pulled to compensate for differences between transmitter and receiver oscillator crystals. The B.F.O. may be tuned to select the upper or lower sideband of the received signal when adjacent signals interfere. The receiver output is passed into the B.T.R. adaptor, the combination of the two receiver outputs taking place in the limiter following the discriminator.

Combination Following Comparison of Signals at I.F.

In the Marconi HR91 receiver the amplitudes of the

Fig. 7. Discriminator type adaptor



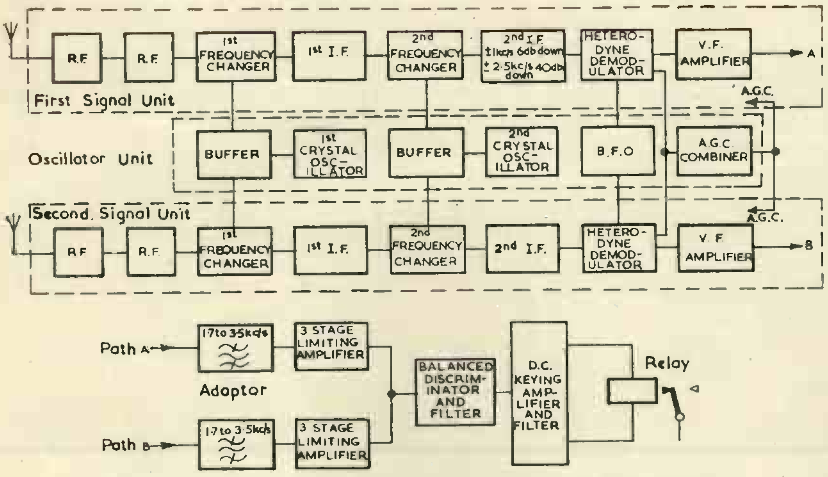


Fig. 8. Combination following comparison of signals after discriminator

signals in the two paths are compared and gated so that only the stronger signal is allowed to reach the discriminator (see page 241).

Codes[13]

As was mentioned before, reliability of a circuit is measured in terms of the number of errors and, particularly where messages are in cipher, it is vital that these errors shall be detectable. The five-unit start-stop code is used in

The Redifon R151 signal unit

the teleprinter and teletype as the most economical code possible for a 26-letter alphabet, though the use of one "case shift" signal, allowing the printer to produce two different characters from the same code, doubles the possible number of combinations. When start and stop pulses are used, the efficiency of code is reduced by some 30 per cent and, in addition, these two signal elements become very important, as their mutilation can throw the printer out of synchronism for several characters. For this reason, the five-unit code is most efficiently used on a synchronous system, the machine speeds being very tightly controlled. The high efficiency of this code means that it is open to undetectable errors and protection can only be obtained by so constructing the code for each character that the mutilation results in a combination which does not represent any other character, e.g. two-condition seven-unit code. An alternative is to arrange the code so that the signal element is made up of two successive conditions and both these have to be reversed to give a false element, e.g. double current cable code. While it is of great value to detect the error, the message is still incomplete and the method of providing the missing information in the minimum of circuit time is very important. Only two of the most common methods can be mentioned here. These are the automatic RQ/BQ system in which over a return channel, the receiver stops the transmission which is restarted at the character which was in error. The other is a full repetition system in which two identical transmissions take place with a delay of, say, eleven characters.

Mechanisms Used in Radio Teleprinter Systems

Before discussing the printing mechanisms, some mention will be made of other machines more related to the type of transmission. For general traffic reasons in large systems, it is convenient to have the signal in tape form so that it may be stored until transmission conditions are suitable and often at this point, use is made of equipment converting the five-unit start-stop code to a seven-unit code, giving greater error detection. The seven-unit code is then worked on a synchronous basis over radio links and reconverted to extend the message to a start-stop teleprinter.

The printing machines most used in conjunction with H.F. radio systems are start-stop machines; the Creed types

The Redifon R151 oscillator unit

7 and 11, the Olivetti T2-CM and T2-ZM and the Siemens-Halske type 68 all being suitable for 50 baud (66 W.P.M.) working. The two latter machines have facilities for producing a perforated tape in addition to the printed message and this tape may be used for transmission at other speeds of signalling. The American Teletype machines were standardized at 45·5 baud working, but developments are taking place towards 75 baud working.

All these machines are mechanically complex and for many applications, a simple mechanism would be a great advantage. The Siemens Hell teleprinter has a relatively simple transmitting and receiving mechanism and uses a code requiring rather wide bandwidth, but building up each character visibly, directly from the code elements. The characters are built up from 25 elements and extra or lost elements appear directly as missing portions of a character or as random elemental lines. At a speed of 50 W.P.M. the telegraph speed is 245 bauds and the code consisting of 49 elements with 25 active elements per character can be used on a synchronous or start-stop basis depending on the machine.

Acknowledgments

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REFERENCES

1. SMALE, J. A. Some Developments in Commerical Point-to-Point Radio-telegraphy. *J. Instn. Elect. Engrs. 94*, Pt. IIIA, 345 (1947).
2. COLE, A. W. Discussion. *J. Instn. Elect. Engrs. 95*, Pt. III, 455 (1948).
2a. BARNES, G. W. As above.
3. VAN WAMBECK, S. M., ROSS, A. H. Performance of Diversity Receiving Systems. *Proc. Inst. Radio Engrs. 39*, 256 (1951).
4. HOLLAND, J. D. Design Consideration for a Radiotelegraph Receiving System. *J. Instn. Elect. Engrs. 98*, Pt. III, 253 (1951). *Also* BRAY, W. J., SMALE, J. A. Discussion (as above), p. 263.
5. HANSELL, G. E. Transmitter Diversity Applied to Machine Telegraph Radio Circuits. *Telegraph, Telephone Age 69*, 12 (1951).
6. HUND, A. Frequency Modulation, p. 33 (McGraw-Hill, 1942).
7. SPRAGUE, R. M. Frequency Shift Radiotelegraph and Teletype System. *Electronics 17*, 126 (Nov. 1944).
8. LYONS, W. Design Considerations for F.S.K. Circuits. Inst. Radio Engrs. Convention, (March 1954).
9. PETERSON, H. O., ATWOOD, J. B., GOLDSTINE, H. E., HANSELL, G. E., SCHOCK, R. E. Observations and Comparisons on Radio Telegraph Signalling by Frequency Shift and On-Off Keying. *RCA Rev. 7*, 11 (1946).
10. RUDDLESDEN, R., FORSTER, E., JELONEK, Z. Carrier Frequency Shift Telegraphy *J. Instn. Elect. Engrs. 94*, Pt. IIIA, 379 (1947).
11. DAVEY, J. R., MATTE, A. L. Frequency Shift Telegraphy Radio and Wire Applications. *Bell Syst. Tech. J. 27*, 265 (1948).
12. BRAY, W. J., LILLICRAP, H. G., OWEN, F. C. The Fading Machine and its Use for the Investigation of the Effects of Frequency-Selective Fading. *J. Instn. Elect. Engrs. 94*, Pt. IIIA, 379 (1947).
13. HAYTON, T., HUGHES, C. T., SAUNDERS, R. L. Telegraph Codes and Code Converters. *J. Instn. Elect. Engrs. 101*, Pt. 3, 137 (1954).

A Narrow Band Frequency Shift Telegraph System

(Pilot Carrier Frequency Shift)

By R. Terlecki*

C.C.I.R. recommendations and the difficult conditions experienced on the H.F. *band demand a new approach to radio telegraphy.*

Brief assessment of the disadvantages of C.W., S.S.B. *and wideband* F.S. *systems are given, followed by a description of a novel radio telegraph system and the equipment developed for its field trials. Finally, conclusions drawn from tests carried out show the important advantages gained from the system.*

THE recent C.C.I.R. Conference in London once again stressed the urgent need for reduction in bandwidth occupied by radio telegraph systems operating in the high frequency radio spectrum. For frequency shift telegraph systems a modulation index between 2 and 5 has been recommended.

The growing post-war demands for new and direct printing communication circuits creates conditions of acute overcrowding and at the present time it can be said that, on many routes, only the brute force of high power transmitters, elaborate and costly unidirectional aerial systems and the highest class of telegraph terminal equipment can offer any reasonable margin of operational safety.

On-off systems although supposedly operating on a single frequency, require an excessively wide band of frequencies on both sides of the carrier to accommodate all sidebands derived from the abrupt manner in which the transmitter is keyed.

A temporary practical solution for congestion together with increasing reliability of operation, was achieved during and after World War II when wideband frequency shift of 500 to 850c/s (known as F.S., F.S.K. or F.S.T.) and single sideband (known as S.S.B.) multi-channel systems replaced some of the orthodox on-off or amplitude modulated circuits.

S.S.B. systems demand large capital expenditure on the transmitting and receiving ends of the link, and costly skilled operation and maintenance. In consequence the S.S.B. systems may be considered only for certain trunk multi-channel inter-continental links where extremely large traffic capacity may be required.

For other purposes many telegraph communication links have been converted to frequency shift operation, mainly by the addition of various units to existing equipment. Fig. 1 is an example of unit construction of this type. The typical installation in this arrangement consists of two radio receivers (not shown in photograph), two F.S. convertors[1] working in dual diversity reception—associated power unit and cathode-ray monitor[2] which gives an instantaneous indication of correct tuning and permits visual assessment of prevailing propagation conditions on the link.

Unfortunately the simple conversion to a wideband F.S. system, with the usual existing radio equipment designed for on-off operation, proves to be not entirely suitable for the present and in particular the future operating conditions. The principal difficulty lies in frequency stability

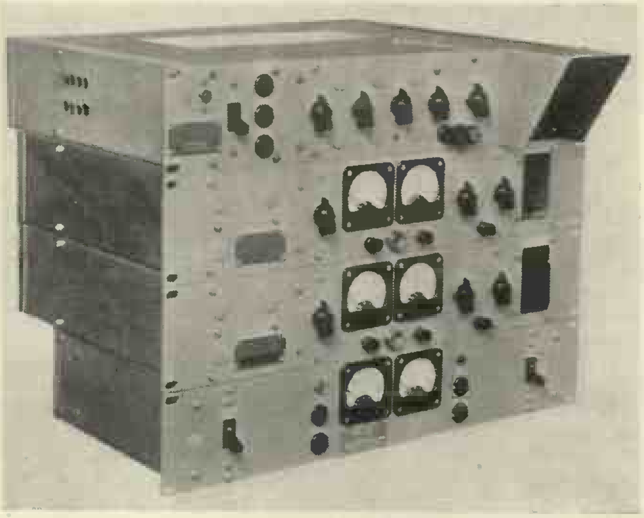


Fig. 1. Unit construction of conversion equipment

which is inherently inadequate, in consequence of which the required bandwidth is unnecessarily wide in relation to the telegraph modulating frequencies employed. Moreover, and for the same reason, such an installation often requires costly continuous monitoring.

Numerous attempts have been made to correct frequency drift or mistuning by relatively complicated automatic frequency control or D.C. eliminating or bias correcting circuits. However, apart from their high cost such facilities have their limitations and lead to deterioration of the circuit by reduction of signal-to-noise ratio and greater susceptibility to noise and adjacent channel interference.

In principle it can be said that for maximum reliability the receiving terminal of a frequency shift circuit should be manned for most of its working period. This is necessary

* British Telecommunications Research Ltd.

on account of the divided responsibility for overall circuit frequency stability between transmitter and receiver. In these circumstances any attempt to reduce the shift leads only to greater difficulties in the maintenance of communications.

Consideration along the lines described led to the development of the Pilot Carrier Frequency Shift (P.C.F.S.) system.

Principles of the P.C.F.S. System

The principal object of the Pilot Carrier Frequency Shift system is to place all the responsibility for frequency stability of the circuit on the transmitter. In consequence any drift or mistuning of the receiver frequency changers produces only a comparatively unimportant variation in the amplitude of the signals.

This is achieved by transmitting simultaneously not one but two closely spaced radio frequencies, one of the frequencies, the pilot, being fixed, the other modulated in frequency according to the transmitted code. The actual separation of the frequencies is equal to the desired audio frequency at the output of the radio receiver. Accordingly, the system provides facilities for transmission of audio frequency signals over a radio circuit without the use of audio modulators in the transmitter.

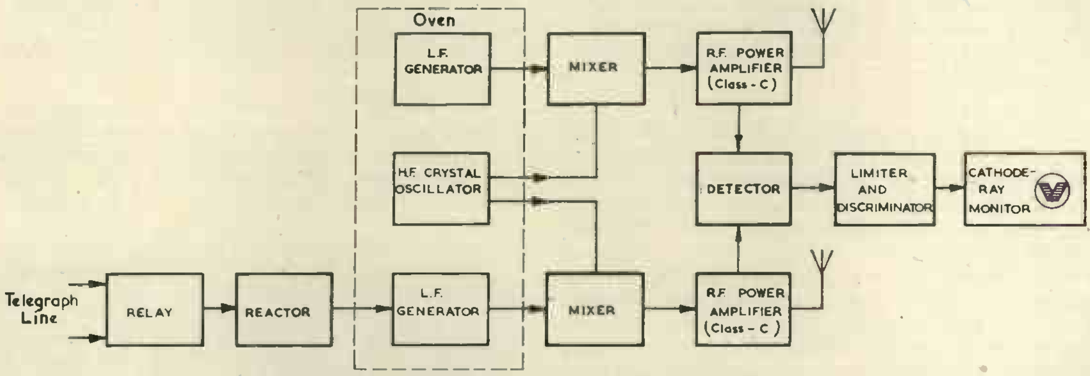


Fig. 2. Arrangement of transmitting terminal

For simplicity the system can be considered as one in which the usual beat frequency oscillator has been removed from the receiver and placed at the transmitting end of the circuit where it serves as a pilot carrier. The resultant audio beat frequency obtained in the detector of the receiver is equal to the difference between the frequencies of the two transmitters. It is independent of the frequency stability of the receiver and can only be altered in amplitude by its selectivity. The final selectivity before extraction of intelligence is provided by the telegraph filters in the terminal equipment.

The exceptionally high overall stability obtained by this system permits a substantial reduction in shift.

Transmitting Terminal

For the practical application of the pilot carrier frequency shift system the transmitting terminal may be arranged as shown in block diagram Fig. 2. A single radio frequency crystal oscillator is fed to two mixers. One of the mixers is fed simultaneously by a low frequency generator of fixed frequency. The second mixer is fed by another low frequency generator whose frequency can be varied between two predetermined values (corresponding to mark and space) by a reactor keyed from the telegraph sender.

The crystal oscillator with both low frequency generators, for preference, should be arranged within a common temperature controlled oven. In this way it can be expected that even in the event of small frequency changes as may occur in low frequency oscillators, they will take place in the same sense and nearly to the same extent and thus preserve the stability of the resultant beat frequency.

The outputs from the two mixers, after selection of the appropriate sideband, are fed independently into suitable radio frequency amplifiers and/or frequency multipliers and finally to class-C power output stages. Due to the very close spacing of the two radio frequencies, this arrangement requires two independent aerials.

By way of example, let it be assumed that the crystal frequency is 3 500kc/s, the fixed low frequency generator, 500kc/s, and the keyed low frequency oscillator has frequencies of 500·450kc/s or 500·500kc/s. After appropriate mixing and selection of upper sideband, without multiplication, the output carrier frequency of one transmitter will be 4 000kc/s. The output of the second transmitter will be varied between 4 000·450kc/s and 4 000·500kc/s. The centre frequency of the receiving discriminator should be tuned to 475c/s and the shift will be 50c/s. It should be noted that, because separate output stages are used for the transmission of the pilot and intelligence signals, full advantage of highly efficient class-C amplifiers is retained; there is no amplifier which has to handle the instantaneous peak power of both transmissions. As an alternative arrangement the outputs of the two mixers may, of course, be fed to a single transmitter. However, the transmitter must then be linear and instead of frequency multiplication, frequency changers must be employed.

The simple monitoring facilities shown on the block diagram will provide for easy monitoring of the transmission.

Receiving Terminal

The receiving F.S. terminal equipment for this purpose does not require any special provision apart from the ability to discriminate between closely spaced mark and space frequencies and a narrow band filter for adequate rejection of noise and adjacent channel interference.

Operation Over an Experimental Radio Link

During the past few months for the purpose of confirmation of laboratory work, an experimental narrow-shift link (P.C.F.S.) was set up over a rather difficult distance of about 100 miles. For the deliberate deterioration of the circuit, the carrier frequency chosen was too high for the path length and time of transmission. In consequence all the usual difficulties occurring on long haul H.F. telegraph circuits were experienced, i.e. deep and fast, flat and selective fading, multi-path propagation, low signal-to-noise ratio and interference.

TRANSMITTER

For the field trials the transmitting terminal was arranged as follows:

Two commercial type F.S. exciters (keyers) were modified to enable one common crystal oscillator to be used for both units. The keyed low frequency generator of one exciter was adjusted to give the necessary low frequency shift, while the second low frequency generator in the other exciter was off-tuned by an amount necessary to obtain the required audio frequency beat between the two radio frequency carriers.

To maintain both mark and space frequencies symmetrically placed with respect to the receiving discriminator, a small portion of the radio frequency output was fed to a common detector. The resultant audio frequency beat, after limiting, was fed into a discriminator with exactly the

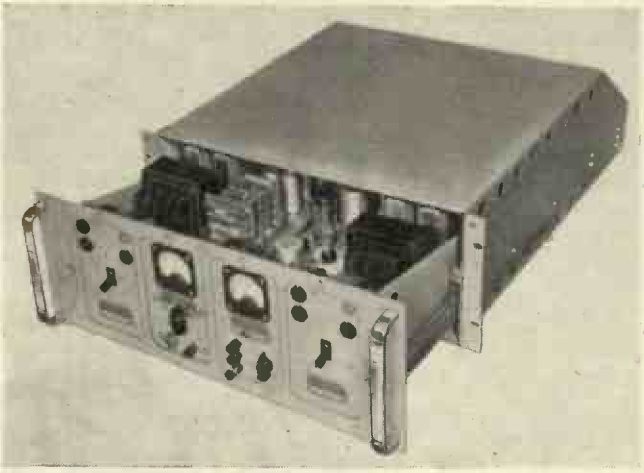


Fig. 3. The receiving convertor

same centre frequency as in the distant receiving terminal. The polar discriminator output as presented on a commercial type cathode-ray tube tuning indicator, gave accurate indication of correct adjustment of the transmitter.

Receiver

The receiving convertor used for trials is shown in Fig. 3. A block schematic is given in Fig. 4. It provides for the conversion of the audio frequency output from the radio receiver into D.C. pulses for the direct operation of the recording mechanism such as teleprinter, tape recorders, etc., without the aid of relays or external D.C. supply.

The convertor consists of the following elements:—

Narrow band input filter providing the necessary protection against noise and interfering signals.

A limiter giving protection against rapid and deep amplitude variations of incoming signals.

High slope linear discriminator permitting wide tolerances on shift actually employed.

Post-detection filtering for removal of audio frequency from discriminator output.

Non-linear amplifier to improve the waveform of the telegraph signals from the discriminator.

Integrating stage with variable negative feedback, providing manual adjustment of the bias, i.e. relative lengths of mark and space elements.

Non-linear D.C. amplifier followed by paraphase power stage (electronic output) which provides, as required, single or double current square wave output and obviates the need for relay and telegraph line battery.

Power supply units, which provide the necessary H.T. and L.T.

The complete receiving convertor with its power supply units was housed in a cabinet 24in deep with front panel 19in wide by 7in high, suitable for mounting on international 19in rack.

For ease of inspection and maintenance, the equipment was sub-divided into four functional units:—

One chassis containing limiter and discriminator.

One chassis containing all circuits beyond discriminator and including line output stages.

Two power supply units.

All four units were assembled on a shelf fitted with telescopic runners to permit the equipment to be withdrawn from the cabinet without interfering with its operation.

The narrow band input filter was mounted on a recess at the back of the cabinet. Inter-connexions between individual chassis and all external connexions were made via plugs and sockets, so that any unit could be quickly and easily replaced.

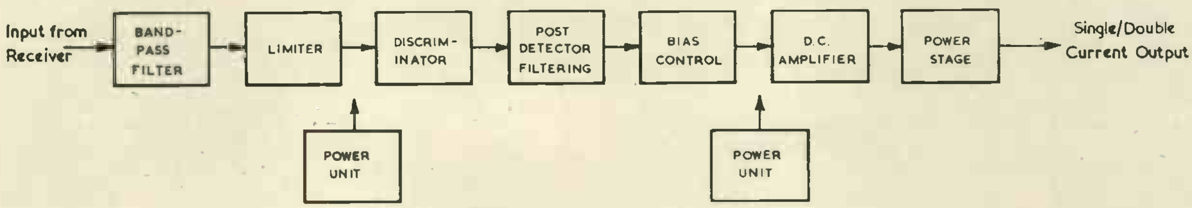


Fig. 4. Arrangement of receiving convertor

Results and Conclusions

The results of the experiments carried out with the pilot carrier on the air show great improvements in overall stability of the circuit and provide the following advantages:—

Considerable reduction of the shift employed (modulation index of 1 or even less can be contemplated) which results in substantial reduction of bandwidth per channel. Despite the fact that the oscillators were not as preferred, in the same oven, it was possible to operate indefinitely with modulation index of 1 or even less. During this time no frequency adjustment was, or indeed could, be made at the receiving end.

On account of the narrowness of the filter pass-band, the signal-to-noise ratio with a given level of signal was improved by several decibels compared with usual type of F.S. receiver.

Unattended operation of radio receiver and its telegraph terminal, which makes it specially attractive for sea or air teleprinter broadcasts.

Use of existing highly efficient class-C transmitters and orthodox radio receivers.

Another advantage of the system is the ease with which multi-channel facilities can be provided by the addition of further close spaced keyed frequencies with the use of the one common pilot carrier. Frequency diversity can be provided by the same means.

Acknowledgment

The author wishes to express his thanks to Mr. F. O. Morrell, the Executive Director, British Telecommunications Research Ltd., for permission to publish advance information on this work.

REFERENCES

1. Terlecki, R., Howell, T. C., Johnson, K. B.T.R. Frequency-Shift Radio Telegraph Equipment. *Strowger J.* 7, No. 2 (July, 1950).
2. Terlecki, R. The B.T.R. Frequency-Shift Cathode Ray Monitor. *Strowger J.* 8, No. 4 (November, 1952).

Frequency-Shift Diplex

By S. C. Heward*, B.Eng., A.M.I.E.E.

A development of F.S.K., *termed Frequency Shift Diplex is described. This system, which is designed primarily for teleprinter working, permits the simultaneous radiation of two independent signals. The equipment necessary to convert a normal single channel system to Frequency Shift Diplex is also described.*

THE technique of frequency-shift keying (F.S.K.) in telegraphy working is now so well established that its advantages over C.W. on/off keying have been proved to be not merely theoretical, but of real practical value. Briefly, in the F.S.K. system the change from "space" to "mark" causes the radiated frequency to shift by a given predetermined amount. For example, if the assigned frequency of the transmitter is f, the space frequency might be $f-f_s/2$ and the mark frequency $f+f_s/2$ (f_s is usually about 850c/s). Detection is achieved by a Foster-Seeley discriminator, preceded by amplitude limiter and followed by low-pass filter circuits. The system is, in fact, frequency modulation, and offers similar advantages, among which are:—

(a) A high degree of freedom from corruption of the signal by random noise:

(b) A high degree of protection against selective fading:

(c) An improved signal-to-noise ratio over on/off keying:

(d) Ease and cheapness of operation. The receiver may be left unattended for long periods, the constantly radiated carrier enabling the A.F.C. and A.G.C. circuits to operate under optimum conditions.

A further development of this basic principle is a system of F.S.K. called, by the Marconi Company, Frequency-Shift Diplex, which permits the simultaneous radiation of two independent signals. This advance results in the doubling of the traffic-handling capacity of any single-channel link, achieved at a low cost and with simple modification to existing equipment.

In this system the carrier frequency is capable of being shifted to assume any one of four values, f_1, f_2, f_3 and f_4, and Table 1 shows how any permutation of mark and space signal on two independent channels may be conveyed by the use of these four frequencies.

TABLE 1
Permutation of Mark and Space Frequencies

CODE 1			CODE 2		
FREQUENCY	CHANNEL A	CHANNEL B	FREQUENCY	CHANNEL A	CHANNEL B
f_1	Space	Mark	f_1	Space	Space
f_2	Space	Space	f_2	Space	Mark
f_3	Mark	Space	f_3	Mark	Space
f_4	Mark	Mark	f_4	Mark	Mark

The table gives the two commonly used codes by which the result can be achieved, while Fig. 1 shows a signal "3" on channel A and a signal "M" on channel B, using these codes.

The carrier is shifted by 400c/s, 800c/s or 1 200c/s to give the four frequencies, which are produced by a frequency modulated crystal oscillator (Marconi FMQ), the lowest frequency being the natural frequency of the crystal. The output of this "keying" is then mixed with the output from the main transmitter crystal drive to produce the final radiated frequency, to be fed to the transmitter.

Decoding is accomplished in the receiving unit by employing three discriminators, one for channel A and two for channel B. These have centre frequencies corresponding to the mean values of f_1 and f_2, f_2 and f_3 and f_3 and f_4

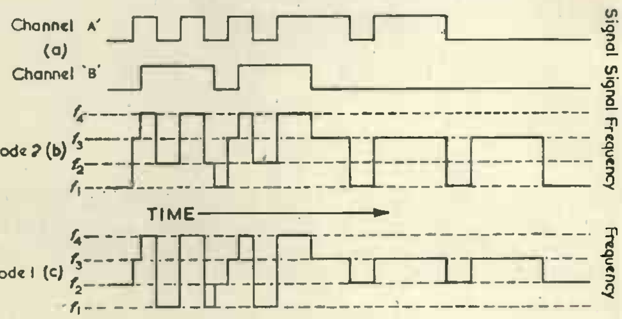


Fig. 1. Figure 3 on channel A and letter M on channel B

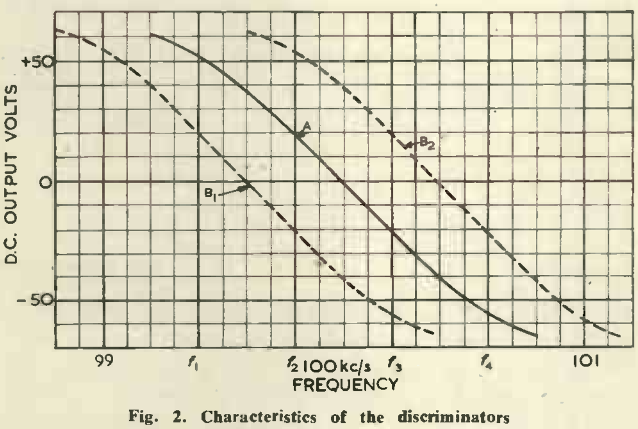


Fig. 2. Characteristics of the discriminators

respectively, and their characteristics are shown in Fig. 2. The operation of channel A depends solely on discriminator A which gives a positive output on space and a negative output on mark. Two discriminators control channel B, however, and these are, in turn, controlled by gating circuits so that discriminator B_1 operates on frequencies f_1 and f_2, discriminator B_2 being cut off, while at frequencies f_3 and f_4 the reverse is the case.

Table 2 indicates which discriminators are operative when code 2 is employed.

**Marconi's Wireless Telegraph Co. Ltd.*

TABLE 2
Discrimination Operative for Code 2

FREQUENCY	DISCRIMINATOR A	DISCRIMINATOR B_1	DISCRIMINATOR B_2
f_1	Operative on space	Operative on space	Inoperative
f_2	Operative on space	Operative on mark	Inoperative
f_3	Operative on mark	Inoperative	Operative on space
f_4	Operative on mark	Inoperative	Operative on mark

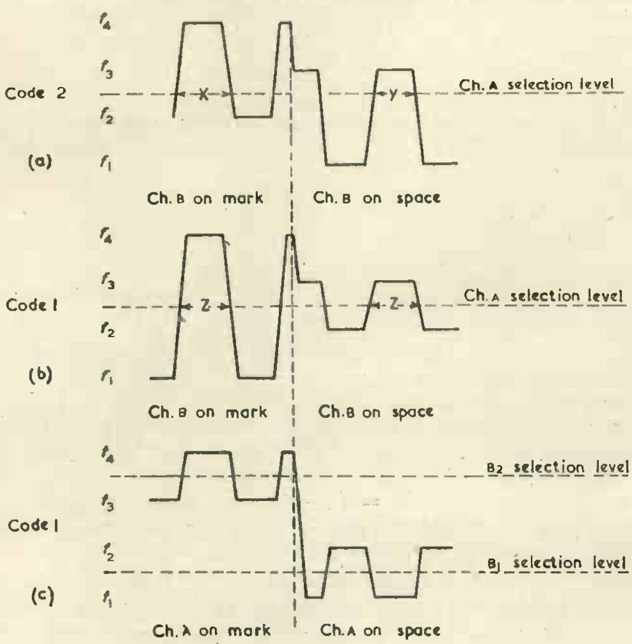
The output of discriminator A, therefore, corresponds to channel A and that of discriminator B_1 or B_2 to channel B.

When it is considered that the keying of a transmitter does not produce square pulses, but pulses with finite rise times, it can be appreciated that distortion will be present due to the shifting bias caused by asymmetry on channel A when channel B is being keyed (difference between x and y in Fig. 3(a)). This is a fault inherent in the use of code 2, which was the original code employed with the equipment in the U.S.A. In subsequent development by British engineers code 1 was devised, and this is now the standard code in use on U.K. circuits. A glance at Fig. 3(b) will show how the asymmetry on channel A is overcome.

Channel B uses two discriminators, as mentioned earlier, and consequently no distortion due to asymmetry of the kind discussed above is present. Unfortunately, however, distortion of a different kind is present due to the "split" in a character caused by the finite time taken to change over from B_1 discriminator to B_2 discriminator when channel A is keyed (see Fig. 3(c)). Due to this feature it is a recognized practice to arrange for channel B to be operated at a relatively low speed and put any fast traffic to be handled on channel A.

Another form of distortion which is inherent in the system as a whole is that due to near-coincidence of keying on the two channels. When a reversal on one channel occurs very shortly after a reversal on the other channel, the resulting frequency change to be handled by the system may be the equivalent of a keying speed very much in excess of either of the speeds in use on the traffic carried,

Fig. 3. Effects of keying distortion



and the equipment will be unable to respond faithfully to the very short peak, with resulting distortion (see Fig. 4). Unless it is possible to synchronize the two keying speeds so that reversals take place together, it is therefore desirable to operate with widely differing speeds, so long as the speeds do not approach a close harmonic relationship.

In practice, with random keying at up to 100 W.P.M. (70-80 bauds), the distortion can be disregarded and for the purpose for which it was designed, namely, teleprinter working, the Diplex system is a great boon to the operating companies.

The Circuit

The two pieces of equipment necessary to convert a normal single-channel transmitter-receiver system to

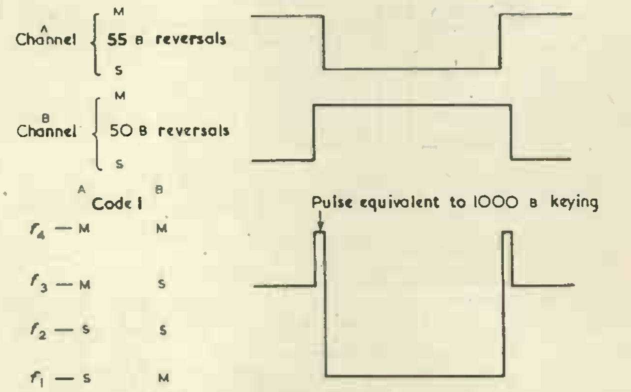


Fig. 4. Distortion caused by near-coincidence of keying on the two channels

The HD.61 drive unit

frequency-shift diplex are the Marconi HD.61 Drive and the HU.14 Receiving Unit.

The HD.61 Drive (Fig. 5)

This is arranged so that it is also suitable for single-channel frequency-shift keying, on/off C.W., M.C.W. or for facsimile working.

In the case of 2-channel F.S.K. working the signals on the incoming lines are applied to two separate chains of triode D.C. amplifiers, each chain incorporating a diode limiter stage. The final D.C. amplifiers control the conduction or non-conduction of three double-diode valves. Corresponding to the four possible conditions of the incoming lines there are four states of operation of these diodes, each of which results in one of four distinct bias potentials (one of which is zero bias), being applied to the grid of a cathode-follower stage. The output of this stage giving normal shift keying of the 3·1Mc/s oscillation frequency on mark and space signals. Stabilized power supplies maintain excellent shift stability.

For on-off C.W. working a keying potential is applied to the control grid of the buffer amplifier valve. The signal passed to the mixer stage is therefore 3·1Mc/s keyed on-off. If frequency modulation of the radiated C.W. or F.S.K. signal is required as an anti-fading measure the output of a 400c/s double-triode oscillator is connected to the control grid of the reactance valve.

In the case of M.C.W. on-off keying an externally generated keyed tone is applied to the suppressor grid

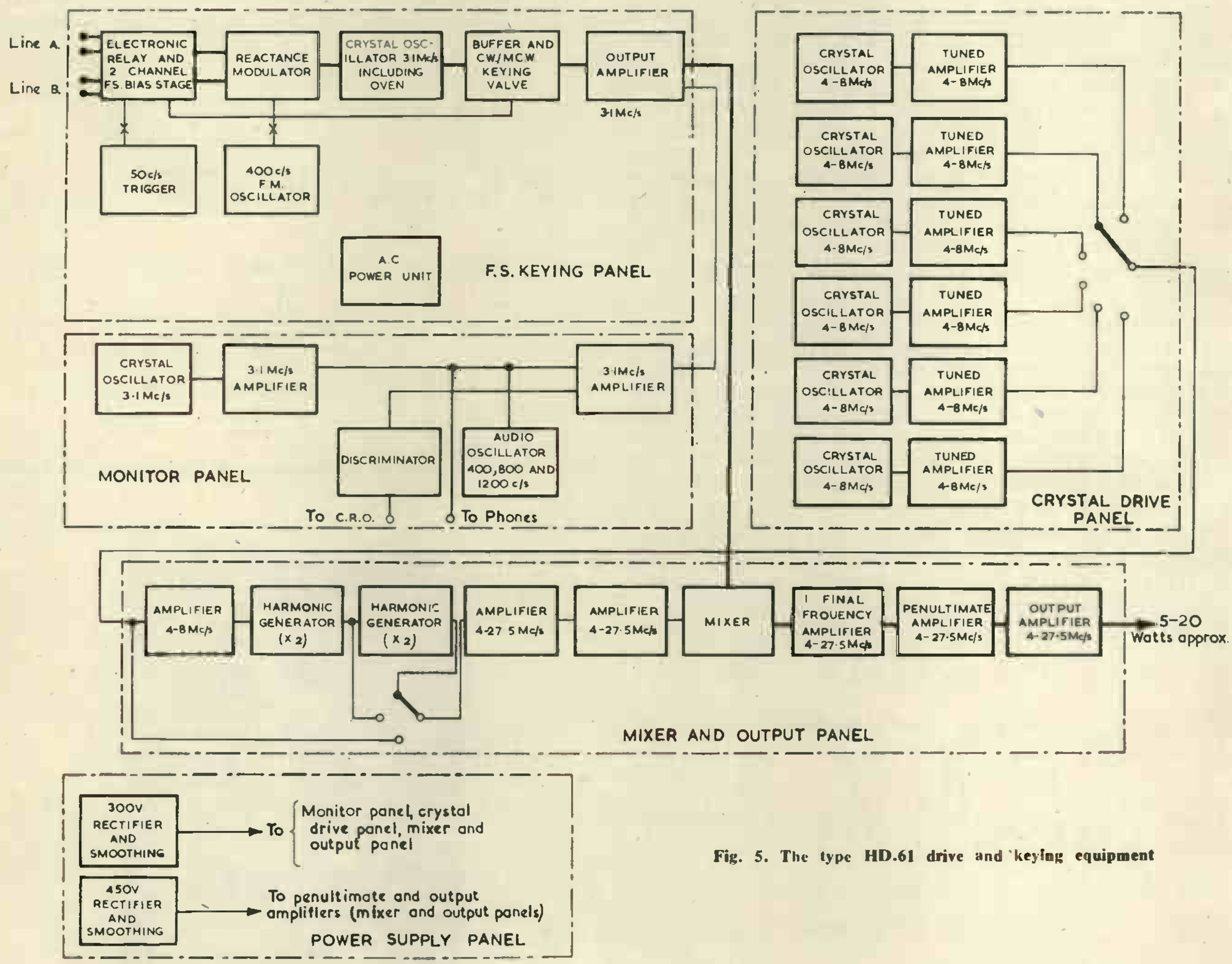


Fig. 5. The type HD.61 drive and keying equipment

is applied to the control grid of a reactance valve, which is coupled to the tuned circuit of a 3·1Mc/s crystal oscillator. The frequency of this oscillator is thus increased in four steps (0c/s, 400c/s, 800c/s, 1 200c/s) corresponding to the four discrete bias potentials applied to the reactance valve.

The frequency shift keyed 3·1Mc/s signal is passed to a pentode valve acting as a buffer amplifier and limiter. The signal is further amplified in a tetrode output stage before passing to the mixer.

For single channel F.S.K. working the keying signal on one pair of incoming lines is applied to a single chain of three D.C. amplifiers. The output from the third D.C. amplifier is applied to the control grid of the reactance valve, of the buffer amplifier. The limiter is removed from the anode circuit and bias conditions are altered.

In order to convert the 3·1Mc/s keyed signal to the required frequency for radiation it is combined in a balanced mixer circuit with a steady drive frequency. This drive is obtained from a crystal oscillator, via harmonic generators when required. The frequencies are chosen so that

$$f_{c_3} = f_{cr} \pm 3{\cdot}1\text{Mc/s}$$

where f_{c_3} = drive frequency from crystal oscillator or harmonic generator.

f_{cr} = required radiated carrier frequency.

The drive frequency originates at one of six crystal-controlled pentode oscillators. These oscillators are designed for operation in range 4 to 8Mc/s. The drive is fed to the mixer stage through a chain of tuned amplifiers and frequency doublers. The number of doublers required will depend on the value for f_{or}, the radiated frequency, and either or both of the two frequency doublers may be switched out of the chain.

The keyed 3·1Mc/s signal is fed in push-pull to the cathodes of a balanced mixer and to the grids of this mixer stage the steady drive frequency is applied, the signal from the tuned circuit of the mixer being passed to a two-stage amplifier. The output amplifier consists of two tetrode valves connected in parallel and capable of delivering up to 20 watts to a transmitter. The output circuit is connected to a coaxial cable termination.

The output from the equipment will normally be at the final radiated frequency of the transmitter and there will be no subsequent frequency multiplication stages. In this way the high shift stability of the keying unit is maintained throughout. If however subsequent frequency multiplication should be employed it is necessary to divide the basic shift in the keying unit by a corresponding factor. There is provision in the reactance modulator circuit for division by 1, 2 or 3.

The built-in monitor circuits consist of a 3·1Mc/s crystal oscillator, similar to that used in the keying unit, followed by a tuned amplifier utilizing a triode-connected pentode. The output of this stage is combined by a metal rectifier with the output from a similar amplifier which is fed with keyed 3·1Mc/s signal from the keying unit.

The resultant difference frequency is heterodyned with tone at 400c/s, 800c/s or 1 200c/s generated by an A.F. pentode oscillator. The resulting beat frequency can be observed on the monitor meter or checked on headphones.

A double-diode discriminator provides a source for checking the waveform of the 3·1Mc/s F.S.K. signal using an external oscilloscope.

THE HU.14 RECEIVING UNIT (Fig. 6).

The receiving unit is designed to fit easily into a standard cabinet or rack, and takes the I.F. output at 100kc/s from an existing receiver. This 100kc/s output is fed via a transformer to a pentode amplifier whose output is divided and coupled to three limiter valves, one in each path. The three Foster-Seeley discriminators are fed with the limiter outputs and each utilizes a double-diode valve.

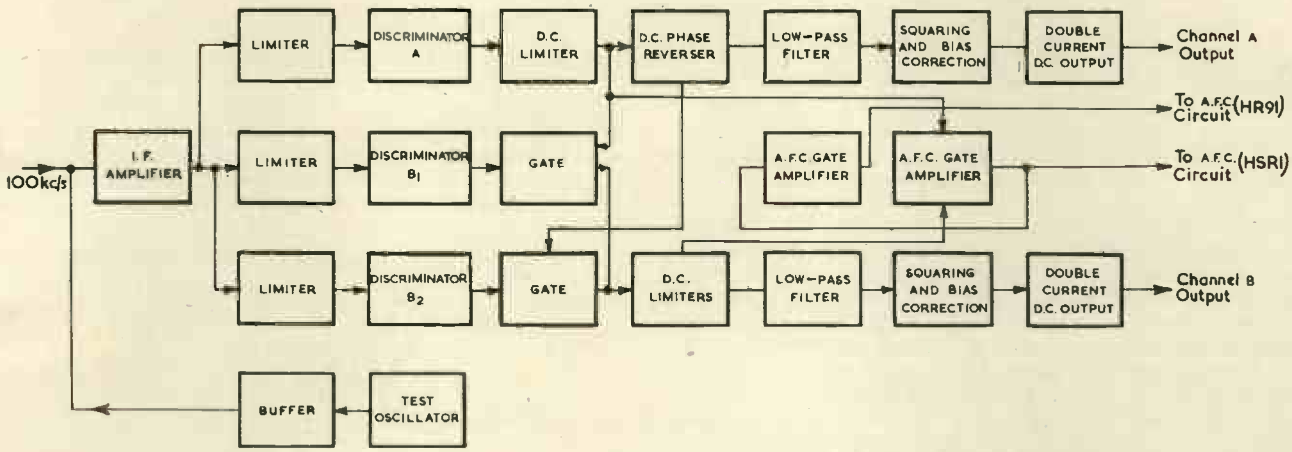


Fig. 6. The type HU.14 receiving unit


The HU.14 receiving unit

The *A* path discriminator output is fed to a series of double triode valves whose function is to shape and square the signal before it is finally amplified in a D.C. push-pull stage. An interstage low-pass filter removes unwanted noise components which are higher than the signal frequency. From two points in this chain, two voltages, having a 180° phase difference, are fed off and applied to the suppressor grids of gating valves in paths B_1 and B_2 respectively. Either one of these valves conducts, therefore, depending on the output of the path *A* discriminator, and so serves as a gate. Depending on which gate is open, the output of either discriminator B_1 or B_2 will be fed to a series of squaring and shaping valves and then finally amplified.

Also included in the unit are A.F.C. control stages which produce voltages to key the A.F.C. gating valves in the main receiver. Reversed keying operation is catered for by a simple switching process, which action by-passes one of the limiter valves and provides the necessary phase reversal.

When the transmitter is on "rest" and no intelligence is being radiated, the maximum frequency will be radiated and the receiving unit will correspond to "mark" on both channels.

An oscillator is incorporated for test purposes, a conventional Hartley type circuit being employed, followed by a buffer stage. By means of plugs and sockets the output may be inserted into the circuit at appropriate points and provision is also made for testing waveforms at various stages by jack connexion.

Power supplies are taken from the main receiving equipment, a filament transformer being the only power component built into the F.S.K. unit.

Naval Low Power M.F.-H.F. Communications

By J. R. Humphreys*

This article points to some of the more difficult problems which arise in the design of low power M.F.-H.F. *communications equipment for naval use, and explains, together with information of a general nature, how these problems have been solved in the design of a new British naval equipment type 619.*

SOON after the end of the last war it was evident to those responsible for supply to His Majesty's Navy of low power M.F.-H.F. radio communications equipment that a situation existed where the available space for this type of equipment was severely limited and was occupied by equipment, either no longer in production or fast becoming obsolete for one reason or another. The Collins "TCS" was typical of equipment in use at the time.

It was therefore decided that a new design of equipment was necessary which could be installed in the space then occupied by the smallest of this type of equipment so avoiding structural alterations to vessels. It was thought reasonable, that with the improvement and miniaturization of components, and particularly valves, during and after the war, that a higher general standard of technical performance could in fact be achieved in spite of the space restriction.

A specification was drawn up giving effect to these considerations and also embodying those features which were found to be desirable as a result of experience during the war, and not present on the current equipment. The Admiralty type 619 equipment has been developed to meet the requirements of this specification and the four units comprising the equipment will be described in relation to this specification.

There is not space here to give the complete specification of this equipment and therefore only those details which are unusual will be described, together with a brief outline of points of general interest. The equipment consists of a high frequency transmitter (1·5 to 15Mc/s), maximum power 40 watts; a medium frequency transmitter (330 to 550kc/s), maximum power 20 watts; a communications receiver covering all frequencies from 60kc/s to 30Mc/s and a power unit which supplies the receiver and any one transmitter.

Perhaps the most important consideration was one of size, which was rigidly fixed at the outset and had therefore a somewhat restricting influence upon the design; calling for very careful thought as to how the available space should be split among the two transmitters and receiver.

The total height, width and depth of transmitters and receiver, as shown in Fig. 1, was specified and also the dimensions of the power supply and control circuit unit. The transmitters or transmitter and receiver had also an alternative side by side mounting position.

From the electrical point of view the specification was mainly conventional but with a number of interesting requirements which are not commonly met in this type of general purpose equipment. Considering firstly the power supply, it was decided that this would operate entirely from A.C. and that D.C. ships would be dealt with by separate rotary convertor installations. The power unit would supply the receiver and any one of the transmitters, and would house all relays and switching required in connexion with remote control operation, which is usually carried out in a control circuit exchange. Microphone input circuits for the H.F. transmitter, keying input arrangements, and additional outlets for the receiver output, were also accommodated in the power unit. These last requirements added considerably to the wiring complication and in the 619 power unit two separate chassis were adopted, with an external interconnecting cable thus easing to a great extent the problem of servicing what would otherwise have been a very heavy and difficult unit.

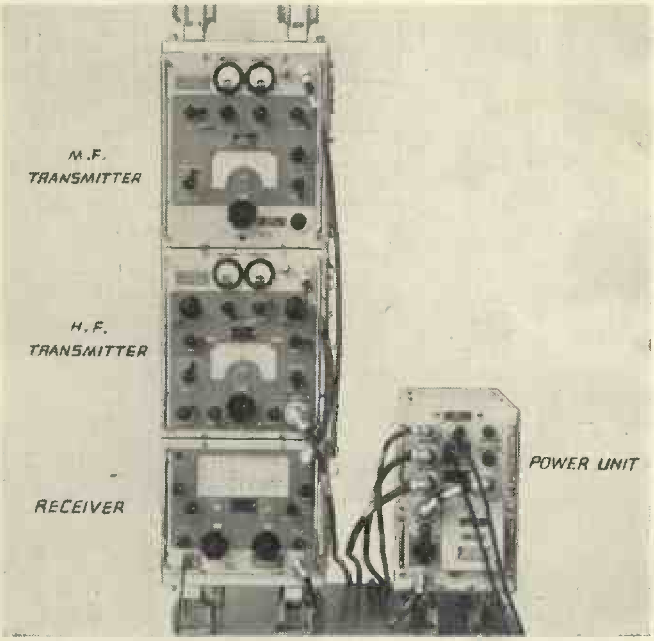


Fig. 1. The complete equipment

Considering next the M.F. transmitter which is used primarily for navigation, homing, or distress working, this had to provide C.W. and M.C.W. operation between 330-550kc/s and was required to load and tune with an aerial which was common to the receiver and would have effective series capacitance ranging between 70pF and 750pF.

An interesting requirement (which applied to the H.F. transmitter as well) was that no damage must arise as a result of an open- or short-circuit aerial. The small length of aerial with which the transmitter must work and the open-circuit short-circuit requirements are unusual and worthy of some mention. Aerials of very low resistance whose capacitance is equal to 70pF (i.e. whip aerials) which are now being used increasingly, present two difficulties. One is that of coupling them into the output stage of the transmitter without serious loss of power in the coupling network and the second is that the more efficient the network the higher the voltage between aerial and earth.

To this latter difficulty must be added the requirements of common aerial working with the receiver, keying speeds of 40 W.P.M. and "listening through" between words.

To satisfy these requirements efficiently a special vacuum

* *Pye Telecommunications Ltd.*

Fig. 2. The vacuum type aerial relay

type aerial change over relay was developed which would follow the keying speeds and also withstand voltages of 3kV R.M.S. with 50 per cent modulation, the voltage limit set by the specification. This is shown in Figs. 2 and 3.

In order to keep the voltage down to this level a π output filter was used and arranged so that it could not be tuned to resonance with short aerials unless a shunt capacitance was switched in on the aerial side of the filter thus automatically reducing the voltage.

The specification requirements that there should be no damage to the transmitter with open- or short-circuit aerial conditions was intended to cover cases of emergency when, say in time of war, aerials are damaged. In such cases communication might well be of extreme importance and the word "damage" was held to mean any excessive dissipation of the power amplifier stage.

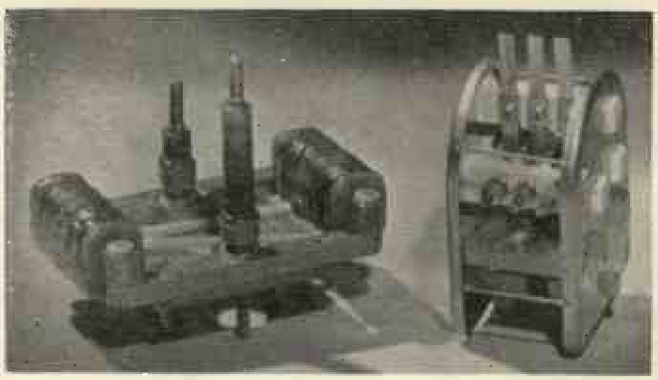
To obtain the required protection an extra power amplifier valve was used in both transmitters and also a clamp valve to stabilize the screen voltage to these valves. This method of limiting dissipation, although more costly of valves and current consumption, has the advantage that the valves are safe however much the aerial circuits are off tune, either unwittingly or during the process of tuning up. In addition it ensures that the valves are operating very conservatively under normal conditions.

A further point of interest is the use of an aerial indicator which was fed from a resonant circuit in track with the master oscillator, this minimizes the possibility of aligning the output circuit to unwanted harmonics.

The 619 H.F. transmitter is in some respects unique in that it solves a matching problem which has not hitherto been tackled seriously in low power transmitters of this small size.

This problem arises because of the use in naval shipping of the large concentric armoured trunk or feeder lines used to connect transmitter to aerial. Depending upon the type of vessel this trunking may have any length between zero and 40 metres and may be associated with

Fig. 3. The external magnetic circuit of the relay showing its connexion to the two threaded pillars which are normally sealed in the glass base and connect with internal magnetic circuits, armature and contact assembly shown on the right



aerials between 6 and 30 metres in length and having a large range of attenuation factor.

This problem is mentioned in detail by W. P. Anderson and E. J. Grainger[1] who give examples by means of Smith charts of the extremely wide range of load impedance that is encountered at the end of the trunk line.

Two of many examples of what may happen under these conditions can be illustrated as follows.

If the length of trunk is of the order of 35 metres and the aerial is about 6 metres then at approximately 2Mc/s the transmitter will be presented with a resistive load somewhere in the region of 2Ω, or in other words the impedance of an open circuit $\lambda/4$ transmission line; while at higher frequencies the sending end impedance may be in excess of $10k\Omega$. In terms of transmitter design this means that the aerial networks are considerably more complex and therefore consume more space than is usual when one can choose the aerial into which to operate. In order to solve this problem the 619 H.F. transmitter employs a π section coupling circuit in its output stage having its

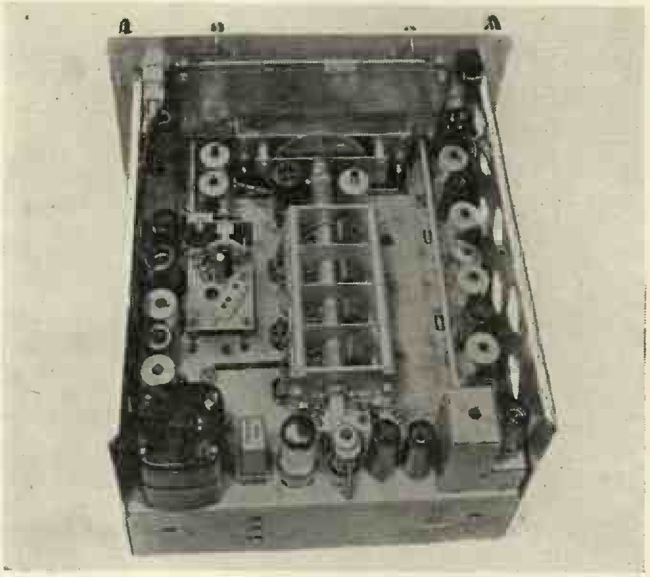


Fig. 4. An inside rear view of the receiver

shunt and series reactances variable over the very wide range necessary to both load and tune the transmitter. The difficulty of tuning the transmitter which normally arises when one is faced with such a large range of variable control is again eased considerably by the use of an aerial monitoring system which uses the combined effect of the rectified voltage from two resonant circuits in track with the carrier output frequency.

These resonant circuits are fed from voltage and current sources and therefore a reasonable indication is always obtained on the aerial monitor meter no matter what aerial and trunk line length is used.

Other features of this transmitter are the provision of eight spot frequencies (crystal controlled), the operation of R.T., M.C.W. and C.W. by local or remote control, and the use, as in the M.F. transmitter, of a high speed high voltage vacuum type aerial relay.

The communication receiver which completes this equipment is the smallest of the four units being only 10 in. by 13 in. by 12 in. and in view of this, and to keep the circuit complexity to a minimum, the receiver was designed as a double superhet on the higher frequency ranges and a single superhet on low frequencies.

The two frequencies used for the I.F. are 460kc/s and 1·4Mc/s and the selectivity of the 460kc/s I.F. is variable in four steps employing a band-pass crystal filter circuit to provide the two narrowest pass-band positions.

The receiver Fig. 4 employs one R.F. stage which, with a first I.F. of 1·4Mc/s, is favourable from the standpoint of protection from image response and oscillator radiation, while permitting a reasonably good noise factor.

Other features include, stabilization of oscillator H.T. supply, series shunt peak noise limit with clipping level adjustment, constant A.F. voltage output over a wide range of output load, and adjustable muting level device which enables listening through when used with the transmitters.

The receiver is directly calibrated in frequency and has course and fine logging scales with a tuning drive mechanism of low mechanical and electrical backlash. There is also provision for the use of a crystal controlled channel between 1·5 and 30Mc/s.

One of the most important requirements of the specification was that defining the minimum radiated field from the receiver. The small physical size and the use of a separate power unit add considerably to the difficulties of reducing oscillator radiation from a wide range receiver of this type to the specified level of less than $0{\cdot}1\mu V/m$ at one nautical mile. The precautions necessary to achieve this low level of radiation include the careful screening and earthing of all R.F. circuits, the use of insulating material for capacitor and coil switching shafts and complete filtering of all leads leaving the receiver case. The receiver was reduced to the minimum practicable size in order to give more room for the two transmitter units with their considerably higher power consumption. In the interest of standardization these latter two units were made equal in size, which made possible common components such as tuning drives and capacitors, cases, packing, etc.

Many of the circuit details are also common to both transmitters. All components and valves in the equipment are to Interservice Specification.

The mechanical design conforms to "Admiralty requirements" for Class A equipment in Climatic and Durability Specification K114.

Acknowledgment

The author wishes to thank the Admiralty, the Directors of Pye Telecommunications Ltd. and Rees Mace Marine Ltd., for permission to publish this article.

REFERENCE

1. ANDERSON, W. P., GRANGER, E. J. Low, Medium and High Frequency Communication to and from H.M. Ships. Inst. Elect. Engrs. Radio Communication Convention 1947.

High Power Aerial Switching

By C. Gillam*

The basic difficulty in high frequency aerial switching is the requirement for avoiding impedance disturbance. This demands double switching, i.e. at the source and at the load. Methods of selector switching are reviewed and some recent switching designs, including one for twin coaxial line, are described.

It is commonly necessary to switch the output of an H.F. transmitter to one of a number of different aerials in order to provide for changes in transmitting frequency or in the target area, or to permit the use of a non-radiating test load. Where important services are involved it may also be necessary to switch in a substitute for the transmitter normally working, either in the event of breakdown or to provide for routine maintenance. On a large transmitting station equipped with many transmitters, complicated switching systems with a high degree of diversity may be necessary. The most complete solution of the problem provides connexion ways between transmitters and aerials so as to permit any transmitter to have access to any aerial, and with as many connexion ways as there are transmitters so as to permit full utilization of the transmitters. Particular circumstances may make restricted solutions entirely satisfactory for the services concerned, with a substantial reduction in cost and complexity. Again, while it might be possible to provide all the facilities desired at a single switching station, there may be a gain in simplicity and a reduction in cost resulting from sub-division of the switching into separate units. It is the object of this article to examine various switching systems, and to describe in some detail one or two recent developments.

An important consideration is the modern trend to full remote control, frequently combined with an illuminated route-indicator diagram where the switching is complicated. This requirement limits the future use of some of the simple but effective switching arrangements which have been in use at many stations.

Random Impedance Switching

In very few instances, and usually only in minor low power stations, the aerials are brought practically to the transmitter terminals, without the interposition of a transmission line. The switching then takes place at random impedance, and apart from careful choice of the insulation material, no particular difficulties are encountered, although quite high voltages may be involved. Ship-board installations are typical in this respect.

Constant Impedance Switching

In all major stations the aerials are fed through transmission lines. Usually an H.F. transmitter is designed to work in conjunction with a transmission line of a particular characteristic impedance, and its output circuits will accept a load impedance within a comparatively narrow range of this nominal value. This range is usually specified in terms of the reflexion factor or standing-wave ratio on the transmission lines and the tolerance tends to vary inversely with the transmitter power. Thus transmitters of less than 1kW rating may accept reflexion factors up to 1/3rd (standing-wave ratios less than 2 : 1) while 100kW transmitters may not accept reflexion factors higher than 1/6th (standing-wave ratios less than 1.4 : 1).

There is usually little difficulty in achieving a reflexion factor considerably smaller than this on a run of transmission line carrying a single frequency, by applying the customary matching techniques. When transmission line switching is necessary, however, the run of transmission line from the switch to the transmitter, including whatever constitutes the " arm " of the switch, may carry a range of frequencies ; its impedance characteristic must, therefore, be flat for the whole range, and the transmission lines on the output side of the switch must all be closely matched.

The commonest types of transmission lines are :—

(a) Coaxial lines, unbalanced to earth. These may be

* *Marconi's Wireless Telegraph Co., Ltd.*

either of rigid tubes with air dielectric, or of flexible or semi-flexible cables, with either entirely solid dielectric, or a dielectric partly of air and partly of solid material. The characteristic impedances of these lines lie in the range from 40 to 100 ohms.

(b) Open-wire lines balanced to earth. Characteristic impedance in the range from 300 to 600 ohms.

Unbalanced open-wire lines are not often used for H.F. transmission because of the difficulty of preventing radiation losses.

Quite apart from the question of whether the transmitter can be made to deliver its power into a badly mismatched transmission line (i.e., with reflexion factors higher than those quoted above) any mismatch on the lines involves greater power losses and higher voltages than on a matched line. There are, therefore, sufficient reasons for aiming at the least possible mismatching, particularly in the case of high power transmitters. The great difficulty in designing transmission-line switches, therefore, is that the switching has to be carried out at the line impedance, and without introducing impedance variations. As a consequence, paralleling a conductor to a number of switch contacts cannot be permitted, since the unused connexions would constitute shunt susceptances. Accordingly, except in those cases where one transmitter is to be switched to one of several aerials, or one aerial is to be

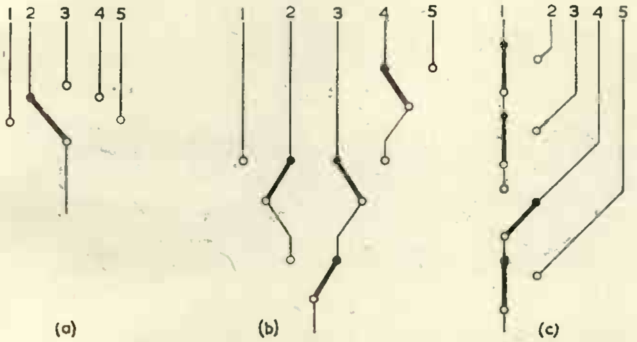


Fig. 1(a). Radial multi-way switch. (b).(c). Cascade of two-way switches

available to one of several transmitters, it is necessary to resort to double switching. This, incidentally, guards against untoward parallel connexion of transmitters or aerials.

There are several reasons tending to a preference for balanced open-wire lines wherever no contrary indications occur, and among these may be cited :—

Cheapness.
Convenience in erection and maintenance.
Suitability for connexion to balanced horizontal aerials.
Simplicity of application of impedance matching techniques by stubs or transformer sections.

On the other hand, the switching problem is very much more difficult for open-wire lines than for coaxials. This is because the higher impedance range implies higher voltages for the same transmitted power ; the cross-sectional area of space required per line is much larger ; and much greater difficulty is found in avoiding impedance departures. Switching stations for open-wire lines have often been designed for outdoor installation, and alternatively, where an indoor installation has been adopted, special and expensive buildings have been necessary.

These considerations have led to the conception of carrying out the switching in either single- or twin- coaxial lines, which permits a much more compact design of the switching elements. The coaxial lines are then continued to a suitable external point where the impedance is expanded in a transformer to match normal open-wire lines.

Types of Selector Switching

Either multi-way switches, or a cascade of two-way switches can be used for selector switching (Fig. 1). Of these, the multi-way switch appears to have the advantage that only one switch contact occurs in each line, so that any impedance variation is introduced once only. It has the disadvantage that all the output lines are brought to a single unit, so that the operating radius may have to be very large. An alternative to the radial multi-way switch is the linear switch of Fig. 2, which employs a telescopic arm. Switches of the types shown in Fig. 1 can be built in two-pole form for open-wire lines. The types as Fig. 1(b) and Fig. 2 can readily be adapted for switching in coaxial lines. A radial coaxial multi-way switch is difficult mechanically, but can be constructed.

Where requirements call for switching between n transmitters and m aerials, with full interchangeability, an obvious

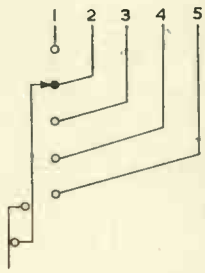


Fig. 2. Linear multi-way switch

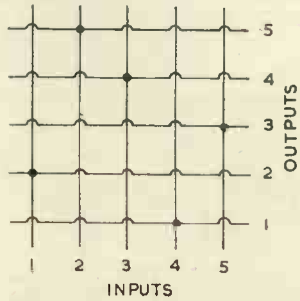


Fig. 3. L.F. Swiss Commutator

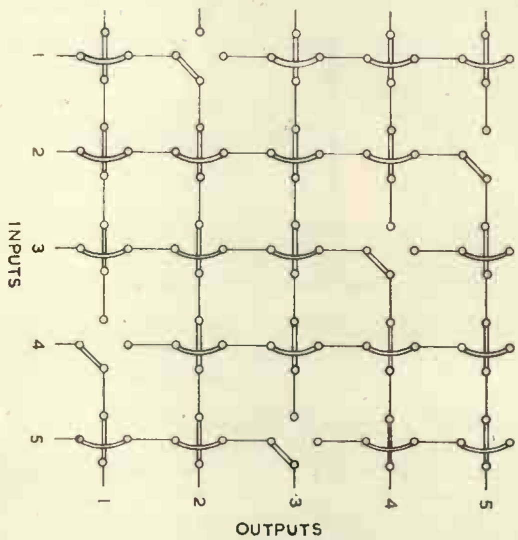


Fig. 4. H.F. Swiss commutator

solution would be the provision of n. m-way switches for the transmitters, and m. n-way switches for the aerials, with nm interconnexions. Such a system, with all the switches in a single plane, becomes unwieldy because of the multiple cross connexions for other than very modest values of n and m, and a three-dimensional construction has to be adopted.

An alternative approach is a variant of the well-known Swiss Commutator. In its low frequency form, shown diagrammatically in Fig. 3, this consists of two sets of busbars crossing at right angles and insulated from each other ; switching is effected by inserting a connector at the required intersection, and mechanical devices may be added to prevent unwanted parallel connexions. The Swiss Commutator can be adapted for H.F. switching in several different ways, but in any of these the sets of busbars have to be interrupted at every intersection. In one form, indicated in Fig. 4, the two sets of conductors lie in a single plane and at the common intersections two-position connectors are used which either join adjacent right-angle pairs, or else bridge both gaps without cross connexions. Switches of this type have been built for open-wire feeders, with the connectors in the form of segments on a drum, and with the two drums for the pair of lines on a common axis.

Another Swiss Commutator scheme is shown in Fig. 5, where a two-way switch is inserted in each bus-bar at each intersection. This system can be applied either to open-wire lines or to coaxial lines, and a particular advantage is that no restrictions are placed on the physical positions of the switches. Also, the capacity of the switch system can be extended as necessary in order to accommodate additional transmitters or aerials. For n transmitters and m aerials, the number of switch units required is $2nm - (n + m)$; thus, for $n = 10$ and $m = 20$, the number of two-way switches is 370. Such a solution appears formidable, although the individual units are quite simple. The switches can be arranged for solenoid operation, and it is then easy to devise a control circuit which will set the sequence of switches necessary for any required through connexion when one master-switch is operated. For balanced open-wire lines, two-pole two-position switches are required, and for impedances around 300 ohms it is not difficult to design these in such a way that a sequence of them causes no serious impedance disturbance. It is considerably more difficult to achieve equivalent results at 600 ohms impedance. A switch of the same general type, designed for twin coaxial lines, using two-way switches for the transmitter busbars, and an arrangement similar to Fig. 2 for the aerial busbars will be described later.

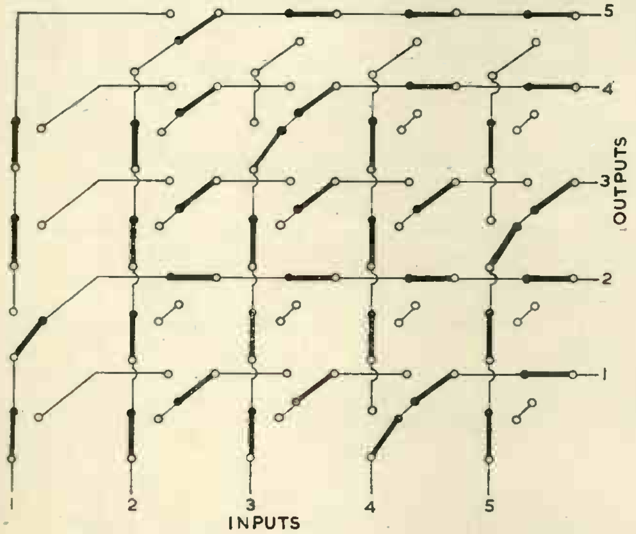


Fig. 5. H.F. commutator with double two-way switching

Group Pre-Selection

In planning transmission-line switch gear for a high power project, it is worth considering how the requirements can be simplified in order to reduce the complexity and cost. For broadcasting services, the aerials are usually of rather narrow impedance-frequency bandwidth, so that for any particular service perhaps four aerials may be necessary in order to provide for all transmission conditions. However, at any one season, not more than two of these aerials may be required. Accordingly, a preliminary seasonal selection of the aerials can often be effected, either by auxiliary switches apart from the main switching station, or by jumper connexions at a special distribution frame. Again, a full schedule of working for the best exploitation of the available transmitters has to be decided and any one transmitter will usually be required to carry a regular programme of services for long periods. It may, therefore, be possible to allocate a group of aerials to each transmitter, and except for emergency provisions, no routine interchange of these aerials with other transmitters may be necessary. These considerations allow the aerials to be sorted out into groups at a distribution frame, and then to be selected individually by simple selector switches, one of which serves each transmitter. This principle has been used by the BBC in this country. Fig. 6 shows the original switching station at Daventry[1]. The distribution frames in the background are provided to enable seasonal selection and grouping of aerials to be carried out by jumper connexions, while the selector switches in the foreground, allocated one to each transmitter, are used for the selection of the required aerials from the groups. The switching is effected manually by shifting over flexible leads provided with hook terminations from one set of eyes to another, the flexible leads being tensioned subsequently by a spring or a weight.

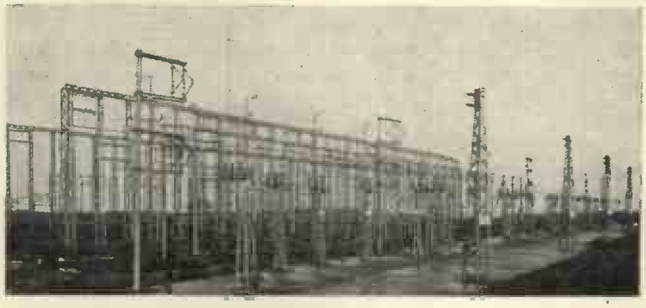


Fig. 6. Daventry switching station

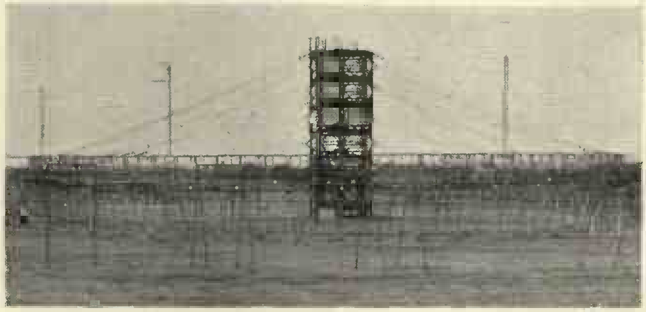


Fig. 7. BBC switching tower

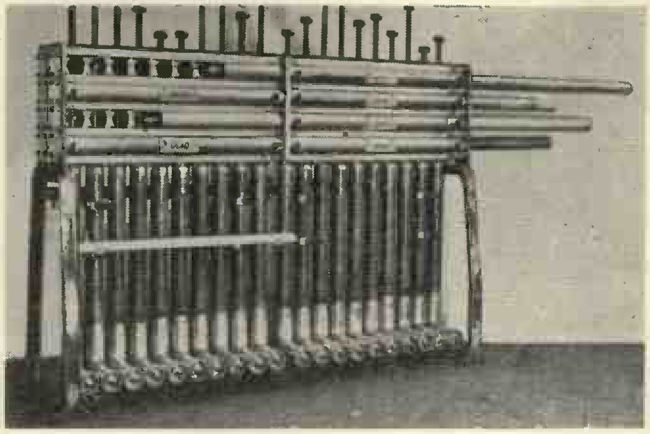


Fig. 8. Coaxial line commutator

Fig. 7 shows a later BBC development, a remote-controlled switching tower at Skelton, near Carlisle[2]. Here all the aerial lines are terminated on the circular frame surrounding the tower, and jumper connexions are made from this to the various storeys of the tower according to the desired grouping. Each storey of the tower contains a motor-driven 7-way selector switch, associated with one transmitter, and controlled from a consol adjacent to the transmitter-control desk. It will be noted that the switching is entirely exposed to the weather, but the operating motor and mechanism are completely protected, and the switches have proved to be quite reliable under all weather conditions experienced in this country.

Early Coaxial-line Commutator

A coaxial-line commutator giving full interchangeability between six transmitters and twelve aerials was designed for use with the early beam stations ; a similar switch, but for eight transmitters and twenty aerials, is illustrated in Fig. 8. These switches have the Swiss commutator arrangement of two sets of transmission lines at right-angles, the outer conductors of the coaxial lines having orifices at each intersection. The inner conductors are telescopic, and can be extended manually until the ends appear at the proper openings where a cross connexion is desired ; the connexion is made by a special screwed connector, and sliding screens are provided for closing openings where live-conductors would be exposed.

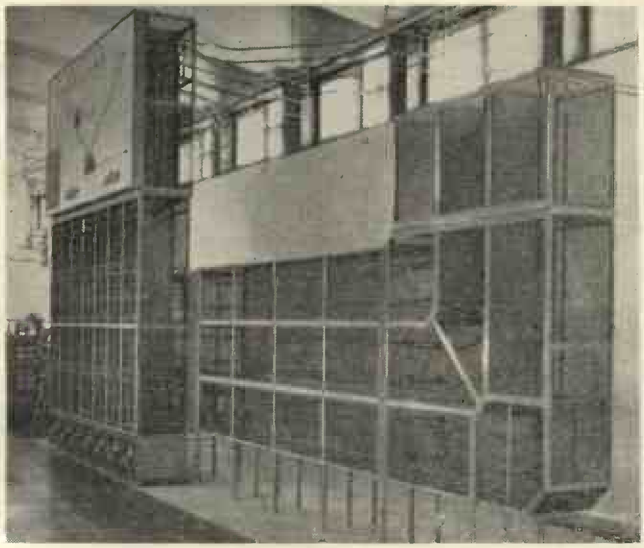


Fig. 9. Swedish balanced line commutator

Balanced Open-wire Commutator in Sweden

An interesting variant of this form of switch has been constructed in Sweden for use with 100kW transmitters, and is designed to work with 300 ohm balanced feeders. The switch is shown in Fig. 9. There are three transmitter-input lines, which enter at the top at the right-hand end, and are taken along in the horizontal screening trunks. There are seven aerial outputs which emerge from the vertical screening trunks at the top of the left-hand end. The conductors in the horizontal trunks extend telescopically, the ends being carried on motor-driven carriages which move horizontally on rails. The conductors in the vertical trunks extend similarly, the ends being attached to carriages which move vertically. Within each carriage, the pairs of conductor ends are twisted through 45°, and terminate in contact pieces which engage when a horizontal carriage and a vertical carriage are moved into positions opposite each other. Of the seven outputs of this switch, four are taken directly to aerials, and the remaining three are taken to a three-storey switching tower rather similar to the BBC-type tower shown in Fig. 7, except that the whole of the switching is enclosed. This tower has provision for nine outlets in each storey.

Fig. 10. Admiralty transmission line exchange

Open-wire Transmission Line Exchange

One of the most interesting of recent aerial switches has been constructed for the British Admiralty at Horsea Island. This is a transmission line exchange for ten transmitters and twenty aerials, rated at 25kW c.w., for use with 600 ohms open-wire lines. Its principle is that of the *nm*-way switches and *mn*-way switches mentioned earlier, but with the *nm*-way switches stacked one above the other, and the *mn*-way switches turned into vertical planes and stacked side-by-side. The *m*-way selectors are carriages moving horizontally on curved tracks, which describe a cylindrical surface with a vertical axis. The *n*-way selectors are a further set of carriages which move vertically on guides situated on the outer face of the cylinder. Both sets of carriages carry pairs of mushroom-headed contacts mounted on insulators, those on the vertical carriages being spring-loaded. When a horizontal carriage and a vertical carriage are brought opposite to one another the corresponding mushroom-headed contacts are pressed together by the springs. The horizontal carriages are traversed by motor-driven flexible lead-screws, which lie in grooves in the curved tracks. The vertical carriages are moved by hand-operated vertical lead-screws. There is a pillar at the axis of the cylindrical surface, to which the transmission lines from the transmitters are brought at different levels, and from which these lines are continued to the horizontal carriages. The line wires are maintained at correct spacing for any location of the carriages by rotating them into a vertical plane at the pillar ; they are returned to a horizontal plane at the carriages. The lines from the vertical carriages are taken as flexible wires to the leading-out

Fig. 11. Admiralty transmission line exchange

insulators which are set in a curved wall coaxial with the exchange ; these wires are long enough to reach the extreme positions of travel of the carriages. This switch was not required to be controlled remotely, but provision for this could be made by motorizing the vertical lead-screws, and adding means to ensure exact registration of the carriage contacts, which in the present design has to be done by observation and manual adjustment. The radius of the arcs is about 14 feet, and the total height of the exchange, including a 4 foot brick plinth is about 20 feet. Realization of the design called for high precision in manufacture and installation, including taking account of the effects on the structure of temperature variations. Fig. 10 shows a general view of the switch, and Fig. 11 shows a pair of carriages with their contacts engaged.

Twin Coaxial Commutator

A commutator has recently been designed for use with twin-coaxial lines at an impedance of 95 + 95 ohms, for transmitter powers up to 20kW carrier, amplitude modulated, or 30kW c.w. It is of unit construction, so that assemblies can be made up to suit a large variety of transmitter and aerial combinations. The largest assembly so far envisaged provides for 14 transmitters and 40 aerials, and measures about 11 feet long, 6 feet 6 inches high and 2 feet 6 inches

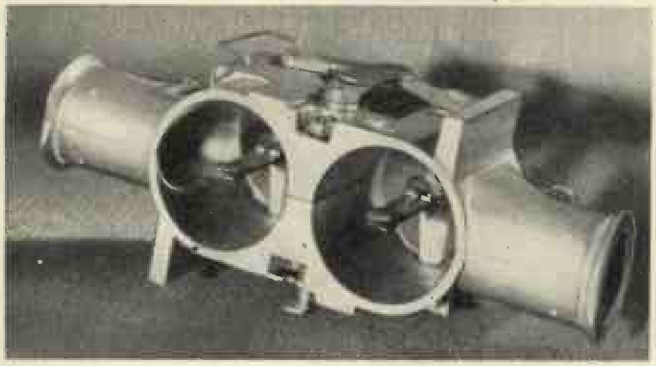


Fig. 12. Switch-unit of twin coaxial commutator

wide ; a space about 34 feet long, 15 feet high and 8 feet wide is required to accommodate it with its input and output feeders, and to provide the necessary access. The commutator can be visualized as a variety of Swiss commutator, with horizontal transmitter lines consisting of cascades of two-way switch-units, and vertical telescopic aerial lines. For each transmitter, a group of aerials is pre-selected manually by adjusting the telescopic lines to the right height and coupling them to the output branches of the switch units. Thereafter, individual aerials are selected from the groups by remote control.

The transmitter trays have positions along them corresponding to each aerial feeder, and up to six switch units can be fitted in each tray at positions corresponding to the aerials forming the group for that particular transmitter. The spaces between the switch units are filled up by plain interchangeable feeder lengths, after which switches and spacers are clamped together by screw pressure. The aerial feeders are brought in horizontally above the switch assembly, and turned down vertically in sequence corresponding to the branch positions along the trays, one line of a twin being on one side of the trays, and the other on the opposite side.

Fig. 12 shows a switch unit which deals with both lines of the coaxial twin. In each line there is a switch arm pivoted on a vertical spindle, and arranged so that it can either lie along the axis of the line, or turn outwards and engage the inner conductor of a side branch. In the straight-through position, the switch arm engages either the pivot end of the switch arm of a following switch unit, or the inner conductor of a spacer length. The two switch arms of a unit are connected by links to a common crank disk on the upper end of a vertical shaft situated between the twin lines ; this is provided with a pair of arms forming a Maltese cross below the unit. Rotating the Maltese cross through 180° causes both switch arms to move together from one to the other of their two positions. Each of these two positions corresponds to a dead centre position of the crank disk, so that over a considerable range of angular movement of the disk about these positions there is very little movement of the switch arms. As a result of this construction it is not necessary to employ a mechanism of high precision to operate the switches. Actually an endless roller chain is used which runs on sprockets at each end of the switch tray ; one sprocket is motor-driven through reduction gearing. The chain is provided with a special link which engages the Maltese cross of each switch unit as it passes, and rotates it 180°. Before the special link arrives, and after it has passed, the Maltese cross is locked by the normal links of the chain in the position in which it has been left. When the special link is at the input end of the switch tray, all the switch arms are turned out and engaging the branch inners ; the transmitter power is therefore switched to the first branches, counting from the input end of the tray. As the special link moves away from the input end past a switch unit, it moves the arms of that switch to the straight-through position, so that power would be switched out at the next set of branches. It will be seen that the duty of the control mechanism is limited to stopping the chain after it has operated completely one switch and before it has started to operate an adjacent one ; no difficulty is found in achieving this with the help of a magnetic brake on the motor shaft.

Provision is made by a simple interchange of connexions at the input end of the switch for any transmitter to take over the switch-group allocated to another transmitter—thus providing for breakdown or servicing. The corresponding control circuits are changed over by plug-and-socket connexions.

Contact Design

In reviewing different systems of switching, and describing switch designs, no mention has been made of contacts and contact materials. In fact, the problem of achieving satisfactory contacts is not very difficult to solve in this particular application. Contacts of large area are generally unsatisfactory since the current will always concentrate along the path of least impedance. It has been found better to aim at contacts of limited area, backed up by sufficient thickness of metal to conduct away locally generated heat. Considerable contact pressure is desirable to break down tarnish or grease film, and up to 200 lb./in.^{2} of actual contact area may be desirable. Lenticular surfaces, ball and plane, and cylinder and plane have all been used successfully. Moving and fixed contacts should be of dissimilar metals to minimize abrasion, but it is rarely necessary to use precious metals for the actual contact surfaces. Copper to phosphor-bronze, or brass to copper are usually satisfactory combinations.

Conclusion

It is quite obvious that finality has not yet been reached in aerial-switch design. In spite of all that can be argued against them, exploitation engineers will continue to ask for full interchangeability of aerials and transmitters, with remote control. The switch designers' task will not be complete until this requirement is satisfied by equipments which cater for the different number permutations of transmitters and aerials, different powers and different impedances, and which do not require feats of precision engineering to accomplish this, or demand slightly reduced scale models of the Albert Hall for their accommodation.

REFERENCES

1. HAYES, MACLARTY. The Empire Service Broadcasting Station at Daventry. *J. Instn. Elect. Engrs. 85*, (1939).
2. BOLT, E. D., MCLEAN, F. C. The Design and Use of Radio Frequency Open-wire Transmission Lines and Switchgear for Broadcasting. *J. Instn. Elect. Engrs. 93*, Pt. III, 191 (1946).

Short News Items

The Physical Society Summer Meeting will take the form of three lectures given in connexion with the General Assembly of Pure and Applied Physics, and will be held at the Royal Institution, 21 Albemarle Street, London, W.1, on Wednesday 7 July at 4.30 p.m., Friday 9 July at 4.30 p.m. and Monday 12 July at 2.30 p.m. Further details may be obtained from the Physical Society, 1 Lowther Gardens, Prince Consort Road, London, S.W.7.

Ardente Acoustic Laboratories Ltd, of 62 Horn Lane, Acton, London, W.3, announce that pressure on their manufacturing space has necessitated making arrangements for moving production elsewhere. Accordingly, a sole and exclusive licence to manufacture and sell their well-known range of intercommunication, marine and general public address equipment has been granted to Easco Electrical Ltd, of 6/8 Brighton Terrace, Brixton, London, S.W.9. These arrangements have no bearing on Ardente hearing aids which are handled from the head office at 21/23 Wigmore Street, London, W.1.

The Chairman of the British Radio Equipment Manufacturers' Association, Mr. P. H. Spagnoletti, at their annual general meeting, said it was estimated that the public paid £28M in Purchase Tax on radio receivers, radio-gramophones and television receivers during the year ending 31 March. Home sales of radio sets rose by 20 per cent and television by 44 per cent, compared with 1952. Export sales fell by 26 per cent and 16 per cent respectively, although radio exports as a whole rose by about 5 per cent.

Enfield Cables Ltd have received during the past few months a series of orders for telephone cables from the City of Edmonton, Alberta. These orders, all of which are being manufactured to Canadian specification, call for more than 80 000 feet of dry-core cable of an overall value of $72 997.

The BBC has installed a new low-power transmitter at its station at Ramsgate, Kent. This is a further step in the plan to make local improvements in the coverage of the Home Service.

Mr. V. J. Faulkner, publicity manager of Crompton Parkinson Ltd, has been elected chairman of the British Electrical and Allied Manufacturers' Association publicity committee. Mr. C. H. Alsop, publicity manager of W. H. Allen, Sons and Co. Ltd, has been elected vice-chairman.

The Department of Atomic Energy announces that Dr. Basil F. J. Schonland, C.B.E., who is at present head of the Bernard Price Institute of Geophysical Research in the University of the Witwatersrand, South Africa, is to be appointed deputy director of the Atomic Energy Research Establishment at Harwell. The appointment will take effect towards the end of the year.

A.K. Fans Ltd, manufacturers of Airmax patented screw fans, announce that Mr. W. H. L. Hewitt of the General Electric Company Ltd has joined the board as technical director. Pending reorganizational changes, a technical services division has been created for advice to all branches of industry and, in the first instance, this service will be based at the company's head office at 20 Upper Park Road, London, N.W.3.

Clan Line Steamers Ltd, have placed an order with Marconi International Marine Communication Co. Ltd, for 24 Marconi Marine radar installations for vessels of their fleet. Installation work will be carried out as occasion arises when the ships are in convenient U.K. ports.

Mr. C. E. Hay has been appointed by Communication Systems Ltd, as technical director. Mr. Hay has been transferred to Communications Systems Ltd, from its parent organization, Automatic Telephone and Electric Co. Ltd.

Mr. H. C. Van de Velde, deputy to the managing director of the Marconi International Marine Communication Co. Ltd, has been elected president of the Comité International Radio-Maritime for the eighth year in succession. The Comité was constituted in 1928 at San Sebastian, its object being the advancement of radio in its application to the safety of life at sea and to marine mobile communications. At present the membership is 28 companies, representing most of the major seafaring countries of the world.

Mr. P. A. Thorogood, general manager of the Electrical Engineers Exhibition, has agreed to be exhibition manager for the eighth exhibition of the Radio Society of Great Britain to be held on 24th and 27th November at the Royal Hotel, Woburn Place, London.

Truvox Ltd. announce that Mr. E. Morris who has held the position of field sales manager with the company for the last six years, has been appointed general sales manager responsible to the general manager and director, Mr. F. Good. Mr. A. J. Catlin has been appointed field sales manager.

Metropolitan-Vickers announce that Dr. C. Dannatt, O.B.E., M.C., M.I.E.E., has been appointed deputy managing director.

The Scientific Instrument Manufacturers' Association announce that, following the resignation of Mr. A. G. Peacock, for seven years secretary of the Association, Mr. E. D. Hart has been appointed deputy director and that Miss G. E. Moss, formerly clerk to the council, has now taken the position as secretary.

The Radio Industry Council announce that radio exports set up a new record in March. Their total value, just over £2 800 000 was £130 000 more than the previous highest monthly total reached in November last year. Radio exports for the first quarter of the year were valued at £6 900 000, representing an annual rate of more than £27 000 000 compared with a record figure for 1953 of £25 700 000.

Dr. G. W. Sutton has been appointed director of research and education for the Siemens Brothers Group of Companies. For the past seven years he has been chief superintendent of the Signals Research and Development Establishment of the Ministry of Supply, to which he was appointed from the Royal Aircraft Establishment, Farnborough.

Standard Telephones and Cables Ltd are carrying out an order for the manufacture and installation of S.H.F. radio networks for the Canadian Pacific and Canadian National Railways. These networks are intended initially for the two-way transmission of 525-line television programmes using a single radio channel for each direction of transmission. As a temporary measure, "Standard" portable S.H.F. radio links have already been installed and are fulfilling the immediate needs for television services during construction of the permanent links.

Marconi's Wireless Telegraph Company Ltd announce that Mr. G. M. Wright, C.B.E., has relinquished his position as engineer-in-chief, but will remain with the company as general technical consultant. Mr. B. N. McLarty, O.B.E., has taken over the position of engineer-in-chief and Mr. R. J. Kemp has become his deputy. Dr. E. Eastwood has replaced Mr. Kemp as chief at the company's research establishment at Great Baddow. Mr. C. Gillam has been appointed chief engineer to the Marconi's communications division and will be working in close conjunction with Mr. A. W. Cole, the manager of the division.

Peto Scott have extended their production facilities with additional factory space at New Haw, Surrey. Here specialized equipment designed and made in their own laboratories has been installed for testing the various types of electronic and radar apparatus supplied under Government contracts.

BOOK REVIEWS

Radio Receiver Design

By K. R. Sturley. 652 pp., 100 figs. Royal 8vo. Part 1, 2nd Edition (revised). Chapman & Hall Ltd. 1953. Price 56s.

THIS is the first part of a two volume book. It gives a detailed account of the radio-frequency portion of a receiver for amplitude modulation starting at the aerial terminal and ending at the detector.

The first chapter gives a brief survey of the various types of modulation in use today, ending with a discussion on noise factor and a description of some possible receiver schematics.

The next chapter deals with valves. After a short section on general principles, the author describes the main types of valve and follows this with a brief discussion on load lines. The valve equivalent circuit is then dealt with at some length, the cases considered being the earthed cathode valve; the earthed grid valve and the cathode-follower.

This is followed by the largest single section of the chapter consisting of some eighteen pages devoted to a discussion on grid input admittance.

The remaining topics discussed in this chapter are valve noise and the effect of the valve on noise factor.

Chapter III deals with aerials, aerial coupling circuits and wave traps. After describing the various types of aerial, the author goes on to consider all the usual types of aerial coupling. Then follows a section on "Interference Reducing Aerial Systems" which includes some ten pages on wave traps. The chapter ends with a note on diversity reception.

The wave traps discussed are all of a rather specialized nature and are intended to reduce interference from strong local stations. This type of wave trap is not so common as the intermediate frequency type which is often fitted to a receiver as part of the design. It is felt that some discussion on the intermediate frequency type of wave trap, particularly on the disastrous effects which can result from an injudicious choice of component values, would have been a useful addition to the subject matter of this chapter.

Chapter IV is on radio frequency amplification. The introduction says: "In this chapter radio frequency is considered in relation to amplifiers which are tunable over a range of frequencies from a minimum of 150kc/s to a maximum of 50Mc/s." The author, however, does not treat this restriction very seriously since on page 286 he discusses a Butterfly Circuit with a frequency of 220-1 100Mc/s.

After a discussion on the parallel resonant circuit the chapter goes on to deal with the characteristics of coils including inductance, mutual inductance, self capacitance and the effects of screening. All the commonly used radio frequency circuits are then dealt with including tunable band-pass filters. Other topics discussed are cross-modulation, valve and circuit noise, instability and band-spreading.

The next eighty pages are devoted to frequency changing including such topics as whistle interference and image suppression. Some of the circuits described seem to be a little outmoded and one assumes that the decision not to rewrite these parts is due to a desire to use existing circuit blocks.

Chapter VI deals with oscillators. Conditions for oscillation are derived for all the usual circuits. To be strictly correct, the assumption given on page 376 should include that of sinusoidal oscillation.

There is a good discussion on frequency stability and methods of compensation, while the problems of ganging the oscillator and signal frequency circuits occupy twenty-two pages.

Since the intermediate frequency amplifier is the heart of the superheterodyne type of receiver, it is not surprising to find that the chapter dealing with these amplifiers is the longest in the book (109 pages). The design of the intermediate frequency transformer with mutual inductance coupling is examined in detail. the results being summarized in a set of generalized selectivity curves on page 453.

The discussion is then extended to include the case in which primary and secondary circuits are dissimilar but have a common resonant frequency. Then follows a section of thirty-two pages on crystal filter circuits.

The topics discussed in the remainder of the chapter include variable selectivity, automatic variable selectivity and valve input admittance and frequency response.

After such a wealth of information on the intermediate frequency amplifier it seems churlish to ask for more, nevertheless it is felt that some reference should have been made to the magnetostriction type of intermediate frequency filter.

The main part of the book ends with a chapter on detectors. This deals with all the detectors likely to be met with in practice, particular attention being paid to the diode detector.

There are six appendices dealing with "j" Notation, Equivalent π and T sections, Lattice network equivalents, Foster's reactance theorem, Tapped Transformer and Lattice Equivalent, Fourier Series.

The book contains a considerable amount of analysis but the author has included sufficient steps to enable the book to be read without too much recourse to pencil and paper. It is clearly printed and well bound and contains 652 pages compared with 442 pages in the original edition.

H. BISSMIRE.

The Fundamentals of Electronic Motion

By Willis W. Harman. 319 pp., 60 figs. Demy 8vo. McGraw Hill Publishing Co., Ltd. 1953. Price 46s. 6d.

WRITTEN for the user of electron tubes, for the student whose primary aim is to gain general understanding rather than specialized information, this work comes up to the high standard that one has become accustomed to expect from Stanford University, where the author is a Professor of Electrical Engineering. The primary objective "is to nurture the ability to deal with new problems and new situations," and with "increased concentration on general philosophies understandings and attitudes."

In a book outstanding for its clarity of exposition the chapter headings are: Fields and Electrons (26 pp.), Motion in a Static Electric Field (39 pp.), Electron Properties and Sources (26 pp.), Motion in a Magnetic Field (35 pp.), Negative and Positive Space Charge (53 pp.), Motion in Time-Varying Field (23 pp.), Space-Charge Waves and Velocity Modulation (38 pp.), Travelling-Wave Amplification (18 pp.), Travelling-Wave Magnetron Amplifiers and Oscillators (28 pp.), Relativistic Electrodynamics (27 pp.). The author's care in selecting some material and excluding other items is understandable when the book is viewed as a text-book for undergraduate as well as for post-graduate students. Among omissions may be mentioned the absence of reference to British workers (a feature to which one is becoming accustomed in books by American scientists) and an inadequate presentation of the fundamental energetics of electron motions. One equation which might have been quoted on page 26 is the equation of energy in time varying fields. This is readily arrived at from the Lorentz equation, and in the M.K.S. units used throughout the book reads differently from that for static fields:

$$\tfrac{1}{2}mv^2 - eV = \int (e/\mathbf{v}\partial \mathbf{V}/\partial t - e\partial \mathbf{A}/\partial t)ds + \text{const.}$$

where the integral is taken over the path s following the electron and **A** is defined by curl **A** = **B** and the term containing it is in most applications, small, unlike the term $\partial \mathbf{V}/\partial t$ which, when $(-e)$ is replaced by $dxdydz$ gives rise to the well-known input losses due to so called electron "loading"—not dealt with by the author.

Errors are few—on page 165, equation 5·69, 2/3 is a misprint for 3/2. Among special items, taken from a plentiful supply at random, one may mention memory tubes (p. 39), space-charge wave treatment of the Klystron, and lateral debunching in an accelerator tube (p. 259). While the author has scarcely succeeded in emancipating the book from "current engineering practice and specific design techniques", for many this would not be regarded as a desirable object. The author is to be congratulated on his clear, helpful diagrams and for his happy knack of providing occasional light relief in a work which is not without its demands upon mathematical competence.

W. E. BENHAM.

Low-Frequency Amplification

By N. A. J. Voorhoeve. 495 pp., 479 figs. Philips Technical Library. Holland. Elsevier Press, Inc., New York. Cleaver Hume Press, London. 1953. Price 50s.

THE declared purpose of this book is "to furnish the sound engineer with a thorough insight into the many subjects which he may encounter in his practical work." The author is an engineer employed by Philips in Eindhoven, and the book is an English translation, being one of a series issued by this company. With this background it is perhaps not surprising that it has a marked bias towards Continental practice and where examples are quoted they are largely of Philips origin. Readers of the Philips Technical Review will be familiar with the style and treatment of the work, and also with the names of many of the individuals who have contributed information for its compilation. The author has been largely successful in achieving his purpose in the chapters on valve and allied technique which form approximately the first half of the book. These cover brief fundamental principles, amplifier valves, preamplification, output amplification, feedback, valve and metal rectifiers and power units. These chapters are detailed and particularly valuable because they have a unified treatment which is rare, since it can come only from a writer who is conversant with both the manufacture and utilization of valves.

Left at this the book would have been wholly excellent, but the scope has been widened to include such diverse subjects as components, transducers, acoustics, amplification and relay systems and measurements. This attempt to cover a vast field has necessarily led to a sketchy and sometimes inaccurate treatment which is not in accord with the detailed excellence of the earlier chapters, and this section can only be regarded as a brief survey. Although this detracts from the value of the work, it is to some extent offset by the copious references which are given at the end of each chapter. These are of particular value to the British reader, containing as they do much Continental material which is not well-known in this country.

The translation is good and errors are not more plentiful than is usual in a work of this type. One particularly annoying thing is that, although the diagrams are all drawn in uniform style, the scale of frequency changes from cycles per second to Hertz and back again with gay abandon as the pages are turned. The typography is excellent, but the high cost of this book should have justified a stronger binding.

D. T. N. WILLIAMSON.

Battery Chargers and Charging

By Robert A. Harvey. 400 pp., 284 figs. Demy 8vo. Iliffe & Sons Limited. 1953. Price 35s.

THIS book describes the new methods used for battery charging and control, together with the older methods which are still in current use, showing how battery control problems have been solved in many industries.

The construction and chemistry of each type of storage battery is first explained; there is a description of the fundamental principles of charging and much general information on charging technique. The book then describes how the principles are used in various specialized applications.

Simultaneous Linear Equations and the Determination of Eigenvalues

Edited by Olga Taussky-Todd and L. J. Paige. 126 pp., 10 figs. Royal 8vo. National Bureau of Standards, Washington, D.C. 1953. Price $1.50.

THIS volume contains the majority of the papers presented at a symposium held at the National Bureau of Standards Institute for Numerical Analysis at Los Angeles from 23-25 August, 1951.

The subject was chosen because of its importance and usefulness to workers in many branches of pure and applied mathematics as well as to workers in fields such as physics, chemistry and aerodynamics.

Applied Electronics Annual 1953/54

Edited by R. E. Blaise. 257 pp. Crown quarto. British-Continental Trade Press Ltd. 1954. Price 20s.

THIS is the third year of publication of this annual and, as in previous editions, there are notes of current interest to those engaged in the export of electronic equipment, with particular reference to the growth of the industry in India.

Also included is a chapter on new devices and components of general interest, information on trends in radio and television throughout the world, and a "Who's Who" for the electronic industry.

LETTERS TO THE EDITOR

(*We do not hold ourselves responsible for the opinions of our correspondents*)

Ten-Volt Effect with Oxide-Coated Cathode

Dear Sir,—I have followed with much interest the discussion between Mr. Fowler and Mr. Taub on the ten-volt effect, published in your October and December 1953 issues (pp. 443 and 535).

I hope I may be permitted to make the following two remarks.

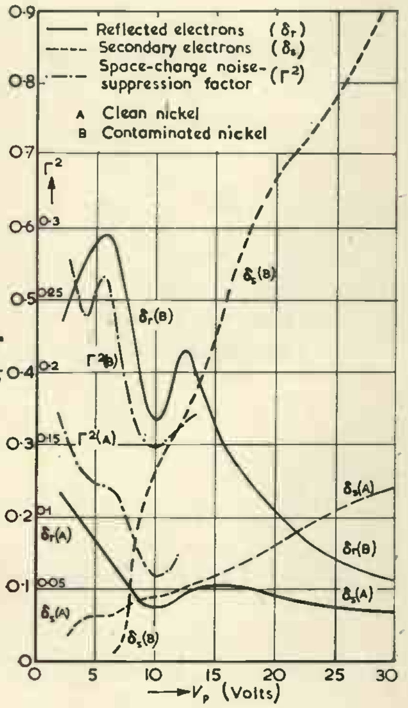


Fig. 1. Results of measurements

(1) At the time of my own investigation (1946)[1], I was wondering why the well-known deviation in the diode characteristic, which in the literature was attributed to reflected electrons from the anode, went upwards instead of downwards, as would be expected if in that region reflected-electron "emission" occurs. After a study of the behaviour of reflected and secondary electrons I arrived at the conclusion that the number of reflected electrons is rather high (10-80 per cent) below an anode potential of 10 volts, and that it can show irregularities as a function of the anode potential. At 10-20 volts the total influence of the reflected and secondary electrons on the potential minimum before the cathode is at its minimum. This occurs because the number of reflected electrons decreases rapidly as a result of the fact that more primary electrons are then able to transfer their energy to the electrons of the metal, and gradually secondary electrons are liberated. Due to the lower velocity of the latter, their number has to become many times greater than the number of reflected electrons to have an influence of the same order on the potential minimum, and this occurs at a potential higher than 10 volts. In considering the influence of these reflected and secondary electrons on the space charge, one must also take into account their angular distribution[2] and the fact that, due to the high reflexion coefficient a number of the reflected electrons will contribute several times to the space charge. So my conclusion was that the observed deviation is due to a decrease in the number of reflected electrons and that the theoretical I_a/V_a characteristic must lie above the measured one.

(2) Mr. Taub is justified in asking for measurements on reflected and secondary electrons of the surface in question, as these were not given in my paper[1]. Some time after this publication, however, I made such measurements, together with other measurements on reflected and secondary electrons from a number of surfaces of interest in vacuum technique. I hope to publish the results in due course. In Fig. 1 the results of the measurements asked for are reproduced; they can be compared with those given in Fig. 8 of my paper[1]. The full-drawn curves (δ_r) refer to the reflected electrons, the dashed curves (δ_s) to the secondary electrons from a clean nickel surface (A) and from the same surface exposed for 50 minutes to the evaporation of an emitting oxide-coated cathode* (B). Electrons coming from the surface and having more than 80 per cent of the energy of the primary electrons were taken to be reflected electrons; those having less than 80 per cent of the primary energy were regarded as secondary electrons. During the experiment a number of intermediate curves were taken, which showed that the change is gradual.

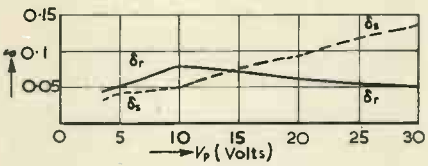


Fig. 2. Curve of soot covered surface

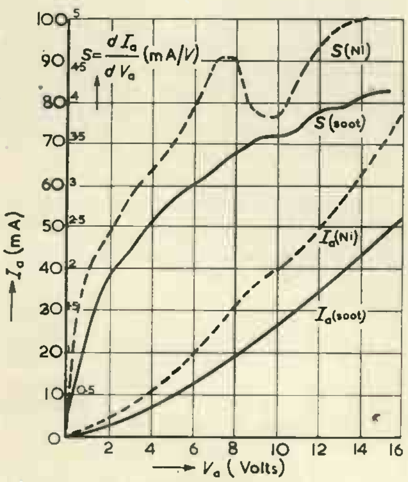


Fig. 3. I_a/V_a and S/V_a characteristics

It can be seen from Fig. 1 that, in the case (B) of the contaminated surface, δ_r has a minimum at $V_p = 10$ volts, and further that when V_p increases from 6 to 18 volts, δ_r (B) drops from 0·6 to 0·24 and at the same time δ_s (B) increases from 0 to 0·6. The deviation at an anode potential of 10 volts in the I_a/V_a characteristic must thus be attributed to a minimum in the number of reflected electrons.

A comparison of Fig. 1 with the figure in Mr. Taub's letter shows that the curves δ_r (B) of the measured number of reflected electrons and of the measured values of Γ^2 (space-charge noise-suppression factor) have the same shape. The chain lines in Fig. 1 show the same agreement between the δ_r and the Γ^2 curves measured on a clean and on a contaminated nickel surface†.

For the sake of comparison I give in Fig. 2 the δ_r and δ_s curves of a surface covered with fluffy soot. This surface has the lowest reflexion coefficient known to me, and this coefficient is particularly small if the soot is pure and $V_p < 10$ volts. A diode with such an anode surface can have an I_a/V_a characteristic practically without irregularities and quite near to the theoretical one. In Fig. 3 measurements are given of the I_a/V_a and the S/V_a characteristics of valves with an oxide cathode, one valve having an anode contaminated with evaporated material, the other having an anode covered with fluffy soot. The slope $S = dI_a/dV_a$ as a function of V_a was measured dynamically with a small A.C. voltage ($\sim$ 0·5mV). It is seen that with the soot-covered anode the irregularities have almost disappeared.

Yours faithfully,

J. L. H. Jonker,

Philips Research Laboratories,

Eindhoven—Netherlands.

REFERENCES

1. Jonker, J. L. H. *Philips Res. Rep.* 2, 331 (1947).
2. Jonker, J. L. H. *Philips Res. Rep.* 6, 372 (1951).

* *Cathode surface (at 770°C) and target were parallel planes separated by 5mm.*

† *The Γ^2 curves were taken from unpublished measurements of G. Diemer and K. S. Knol.*

Q measurement by Marconi

Famous for years in the field of communication measurement, Marconi Instruments offer TF 329G for determinations in frequency range 50 kc/s to 50 Mc/s, and TF 886A for the range 15-170 Mc/s. While both instruments are primarily designed as direct reading Q meters, either may, of course, be employed for a variety of indirect measurements — such as the capacitance and phase defect of condensers — carried out by the normal reasonance methods. In addition, special jigs are available for T F 329G for the investigation of dielectrics.

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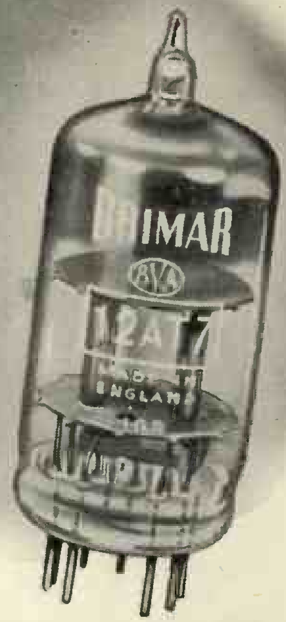

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And now a few words about service. Our unique Monthly Service covers primarily the despatch of "The General Radio Experimenter," a monthly house organ published by "G.R.". In this Journal is published all information concerning new "G.R." items, so that all readers are kept abreast of latest developments. In addition there often appear authoritative articles of great importance covering many aspects of laboratory measurements, as well as "production practice."

The "General Radio Experimenter" service is entirely free and there is no expressed or even implied obligation to make purchases. We do, however, request certain reasonable information from applicants for admission, these being: Surname, full Christian Names, full address of employers (if not self employed), and, if possible, type of work or chief interests. Please also state academic qualifications. Additions to our lists are entirely at our discretion.

THE "G.R." EXPERIMENTER IS APPROACHING ITS 30th BIRTHDAY

All applications should be addressed to:

CLAUDE LYONS LIMITED

ELECTRICAL AND RADIO LABORATORY APPARATUS

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5 Germanium Diodes

for the specialized equipment designer

Where small size and stability of characteristic, unaffected by repeated cycles of humidity, are of first importance choose STC diodes, which will give you complete reliability. The five types described below are available from stock, and others are in course of development.

Abridged Data at 20°C	TYPE NUMBERS				
	2X/102G	2X/103G	2X/104G	2X/105G (CV448)	2X/106G (CV425)
Peak Inverse Voltage (V)	85	30	30	100	70
Minimum Reverse Resistance (kilo-ohms)	500 (at 70V)	100 (at 20V)	100 (at 20V)	500 (at 50V)	50 (at 50V)
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Comprehensive data sheets may be obtained from :

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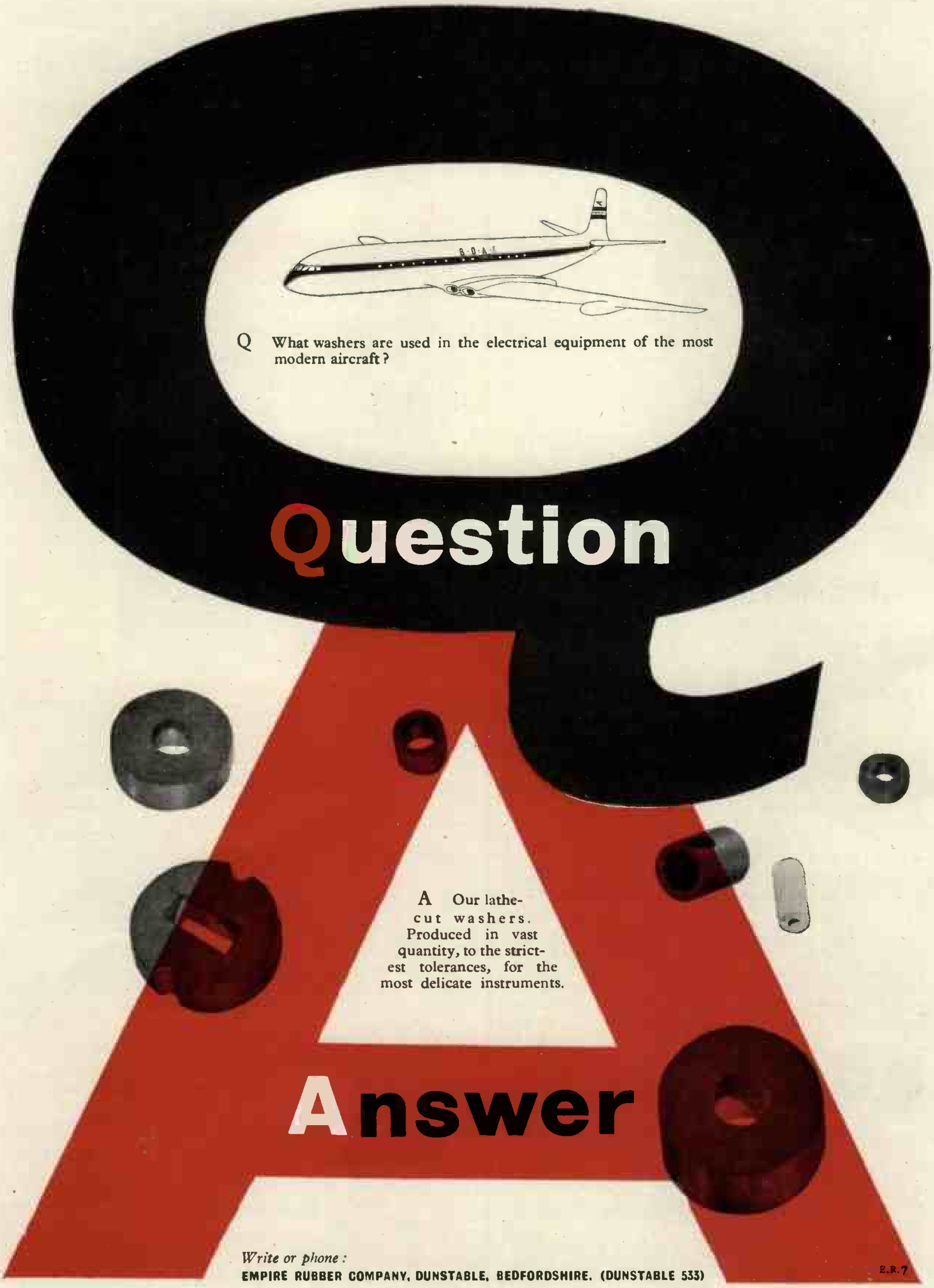
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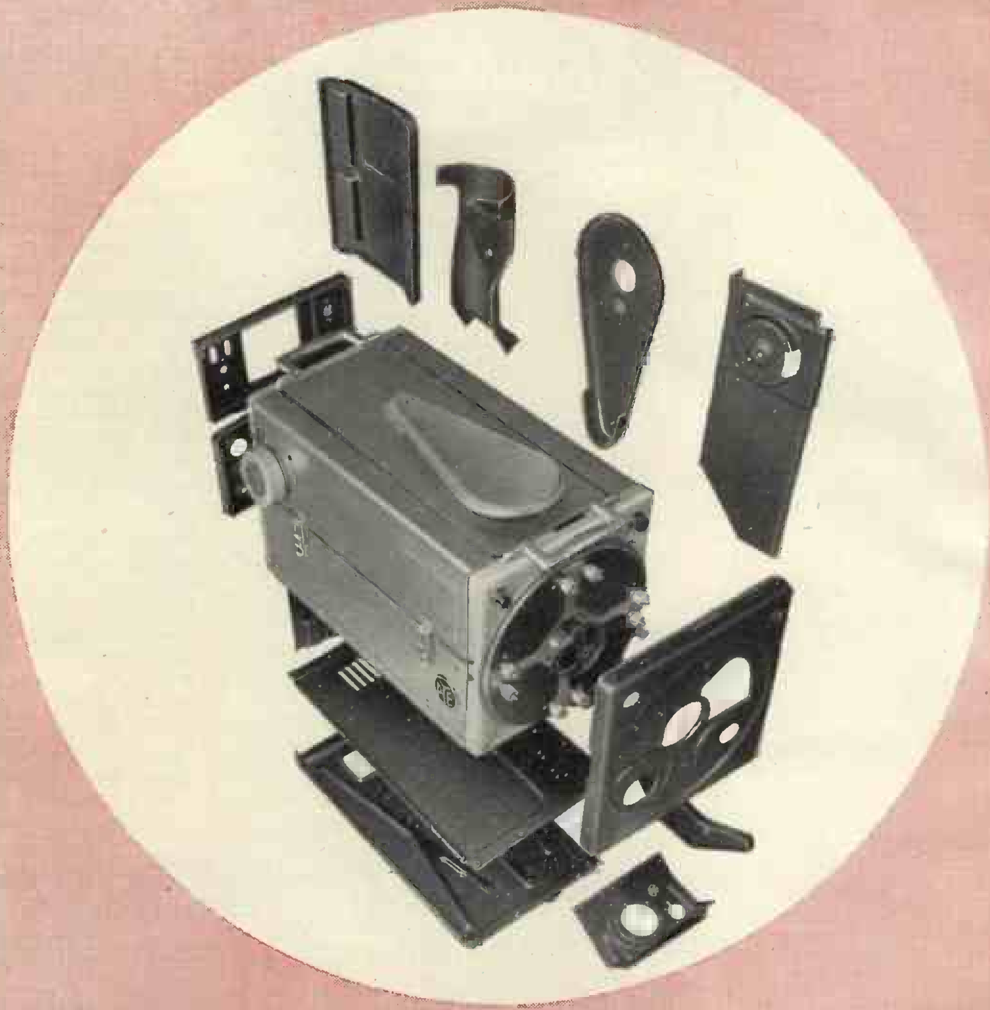

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This advertisement was prepared with the co-operation of PYE of Cambridge.

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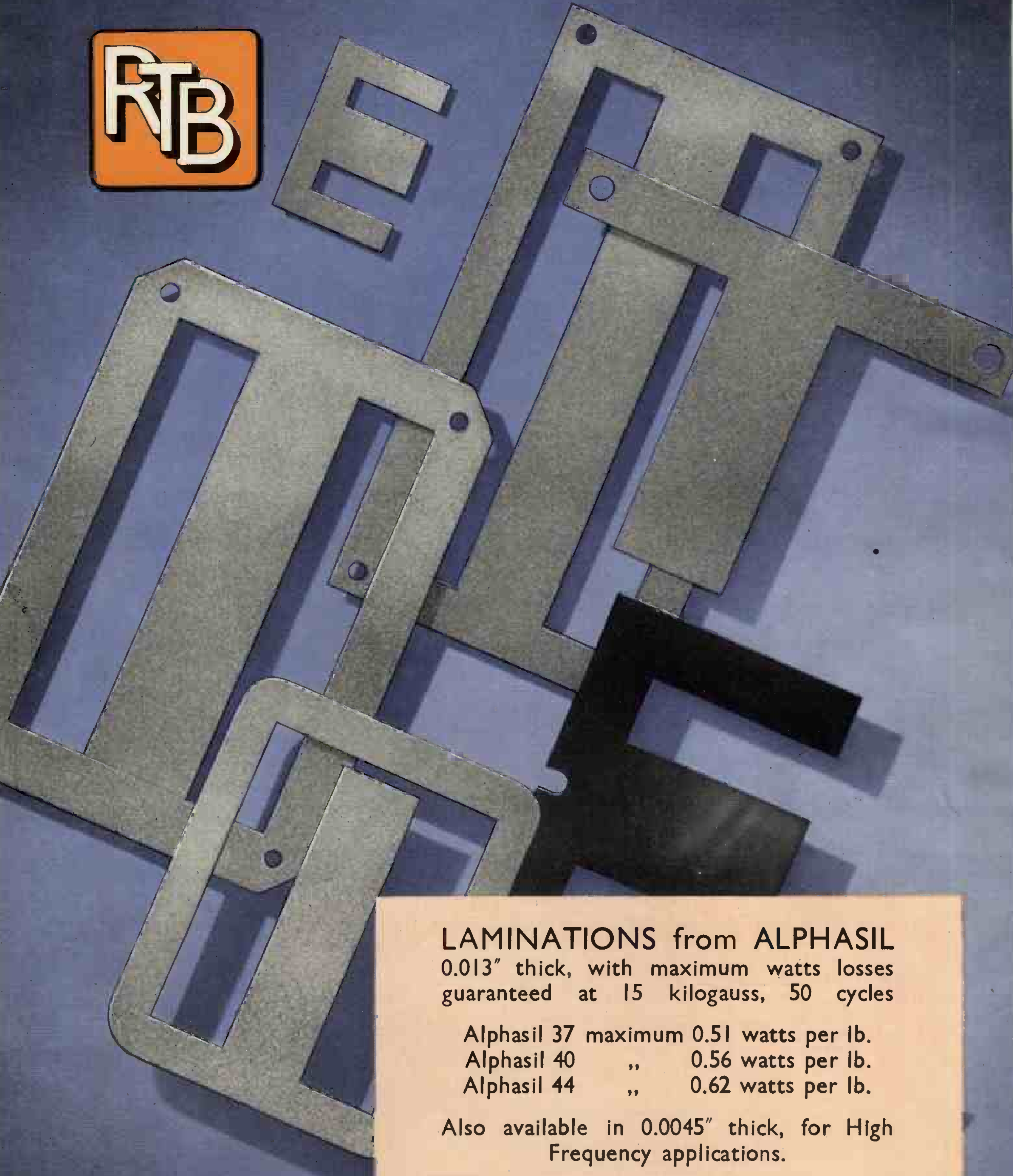

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0.013″ thick, with maximum watts losses guaranteed at 15 kilogauss, 50 cycles

Alphasil 37	maximum	0.51 watts per lb.
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Also available in 0.0045″ thick, for High Frequency applications.

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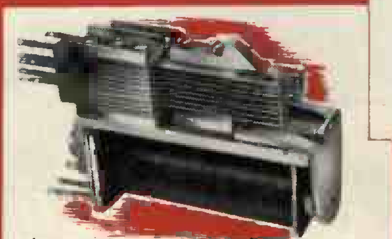
FOR ELECTRONIC ENGINEERS BY AUTOPHONE LTD



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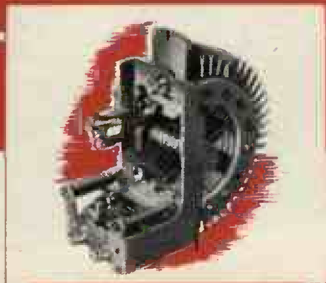

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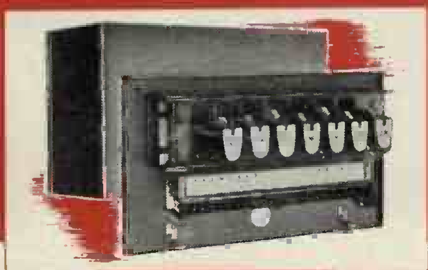

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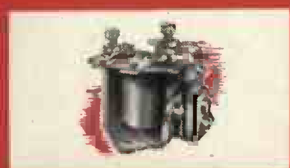

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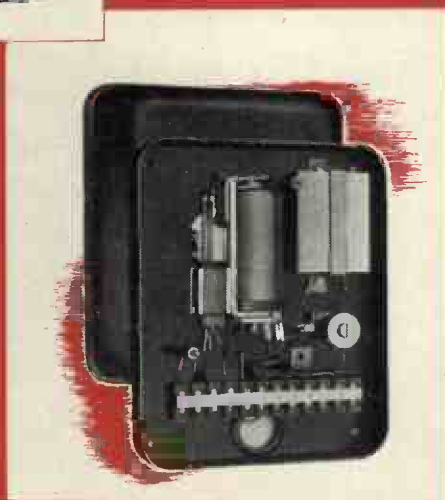

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A.I.D. Approved **Contractors to H.M. Government.**

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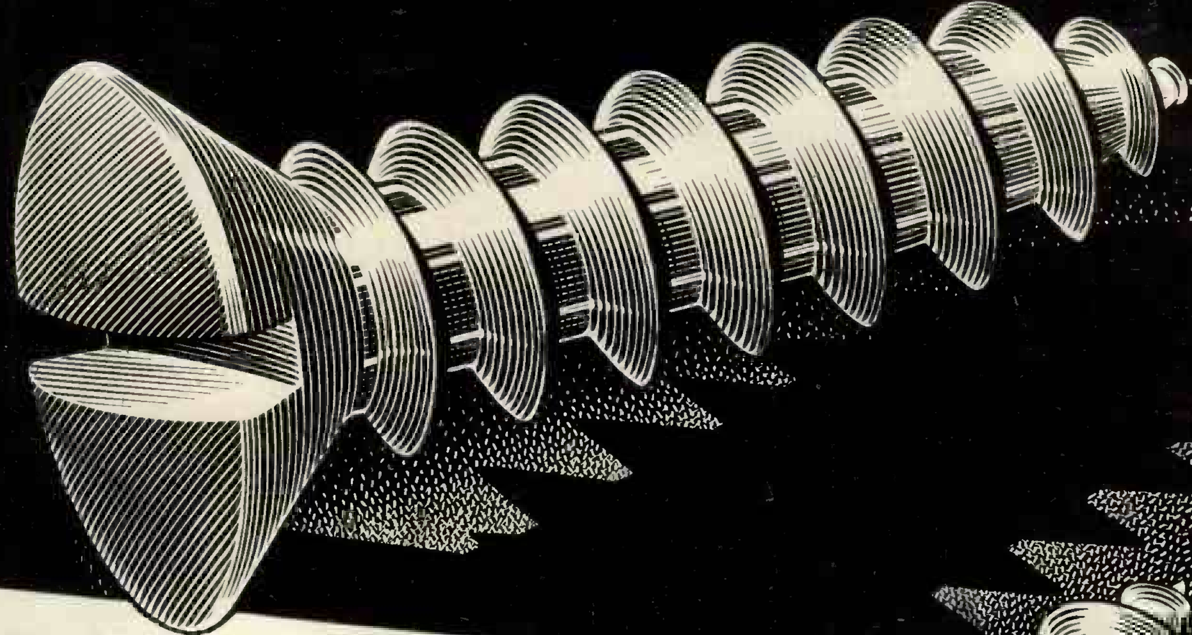

Mullard Ferroxcube being extruded into rods for H.F. cores.

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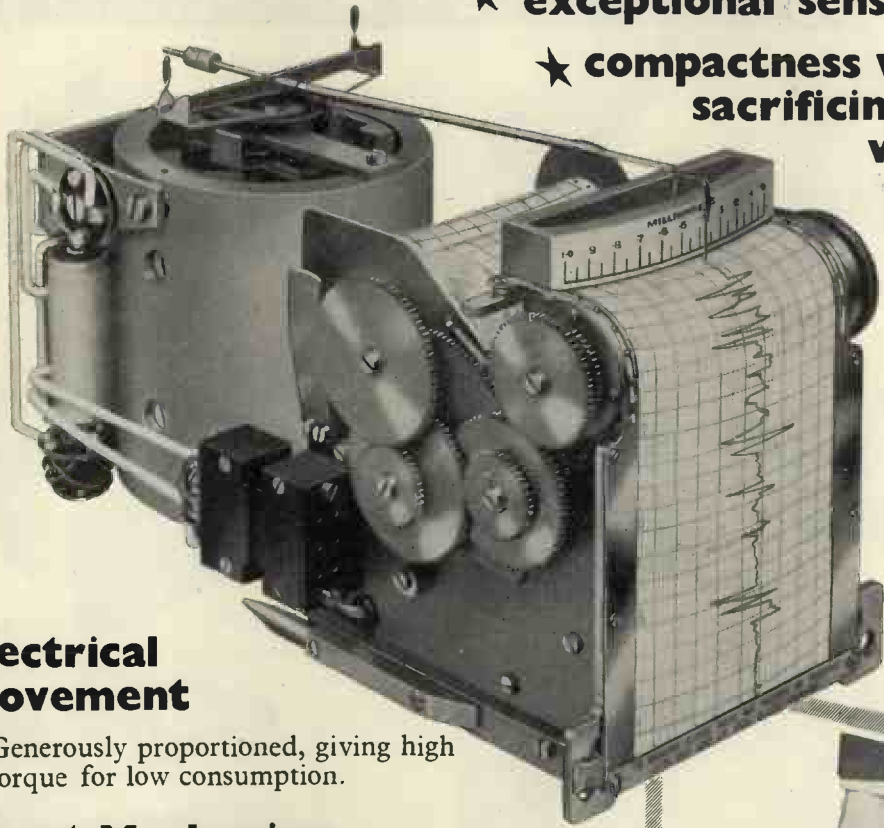

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Compact, removable without disturbing the electrical movement and can be re-loaded with ease and safety.

Available over the full range of power requirements and tachometers. Also available in special forms telecommunication and electronic service. Standardised designs available for quick delivery.

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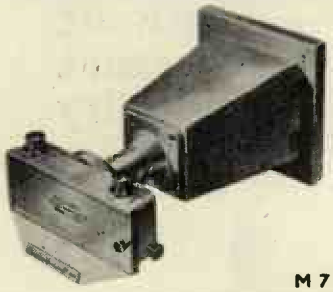
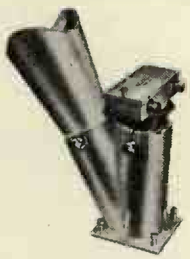
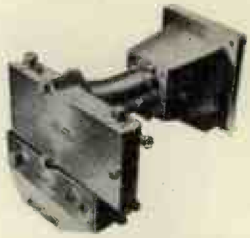

M 726


M 800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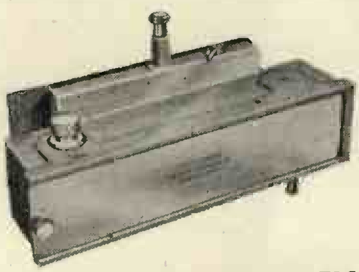
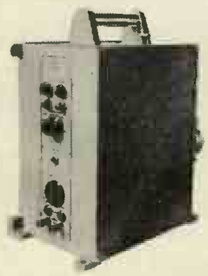

M 725


M 731


M 906


M 735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BR 1091—BXH

FOR WIDE RANGE FREQUENCY AND VOLTAGE

AUDIO FREQUENCY SIGNAL GENERATOR

Model LO63

Accuracy to ± $1\frac{1}{2}$% or 0.5 cycle

FREQUENCY RANGE: 50 cycles to 55,000 cycles.
BASIC RANGE: 50 - 550 cycles direct reading on a 6" diameter scale over an arc of 300.
MULTIPLIER: 1, x 10, x 100.
TOTAL SCALE LENGTH: 48".
Alternatively 30 - 33,000 cycles or 10 - 11,000 cycles.

- *Completely Self-contained*
- *Operates from A.C. Mains—Stabilised Voltages*

Here is a standard calibrated audio frequency voltage generator designed to cover a wide range. The use of high value capacity components in the bridge circuit allied to the two valve phase-shift oscillator which is equipped with fully automatic electronic feed-back control, results in a circuit of exceptionally high stability.

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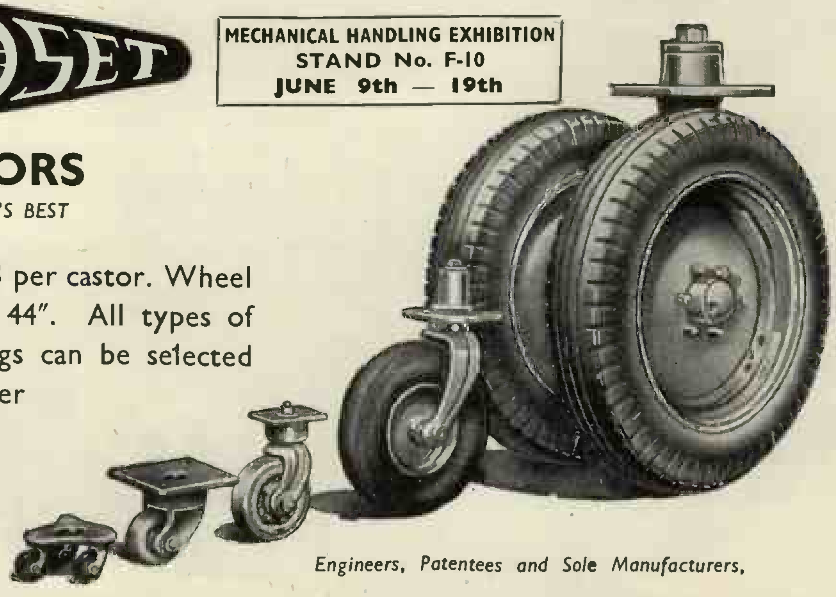

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The Statigun measures potential gradient in air over the range 0-300kv/ft. Attachments enable insulation resistance up to 10^{13} ohms and surface charge density up to 3×10^{-9} coulombs/cm^2 to be measured.

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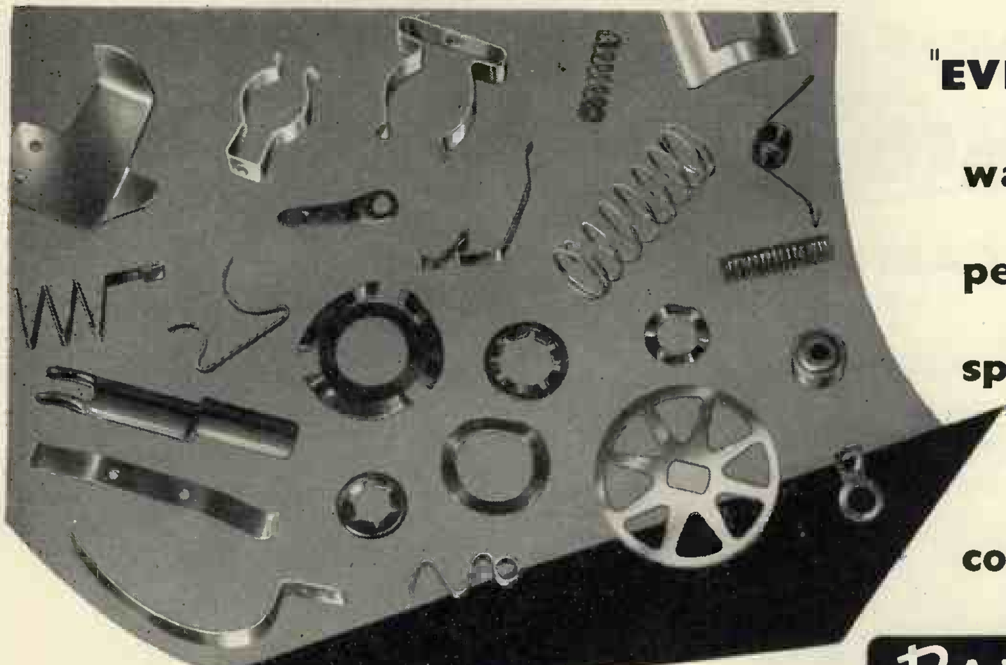

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springs

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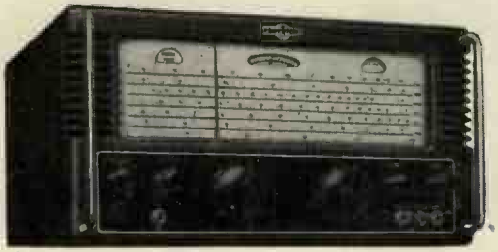
EDDYSTONE

MODEL '770R'

V.H.F. COMMUNICATIONS RECEIVER

FREQUENCY RANGE 19 Mc/s. to 165 Mc/s. CONTINUOUS COVERAGE



- Highly efficient signal frequency circuits.
- Substantial diecast rotary coil turret.
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- Robust construction and outstanding reliability.
- "S" Meter. Noise Limiter. Muting circuit.
- Preferred type valves.
- Finest workmanship throughout.

- A. C. operation. 110-250 volts. 40-60 cycles.
- Dimensions $16\frac{3}{4}'' \times 15'' \times 8\frac{3}{4}''$.
- Weight 60 lbs.

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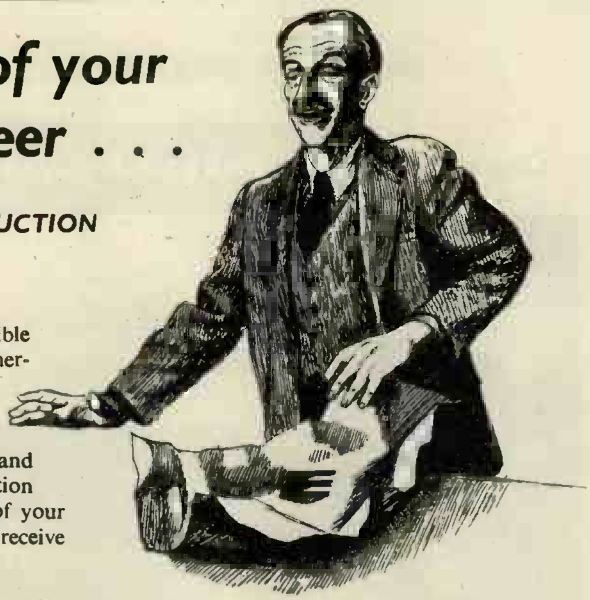

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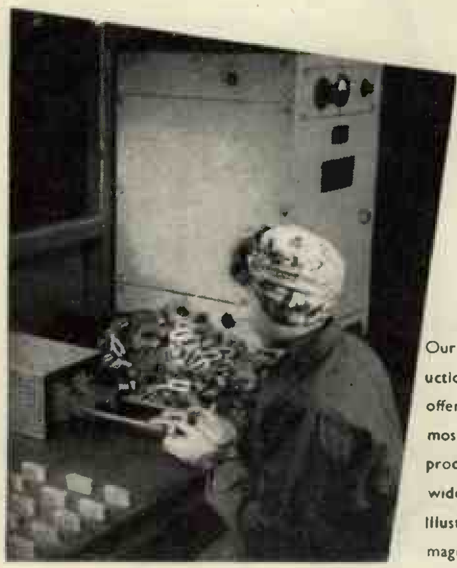

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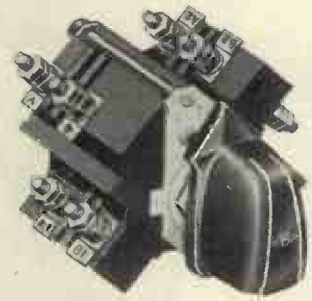

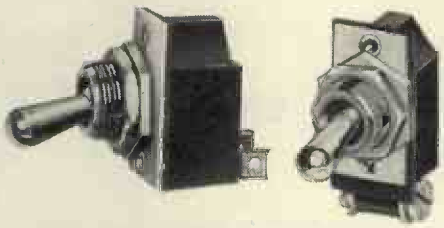

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INDISPENSABLE FOR MINIATURE ELECTRONIC EQUIPMENT.

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THE SMALLEST, LIGHTEST, FASTEST, MOST EFFICIENT, RELIABLE, AND VERSATILE SOLDERING INSTRUMENT IN THE WORLD WITH A FULLY INSULATED MAINS ELEMENT WHICH IS FLASH TESTED DURING MANUFACTURE TO 1,000 V. A.C.

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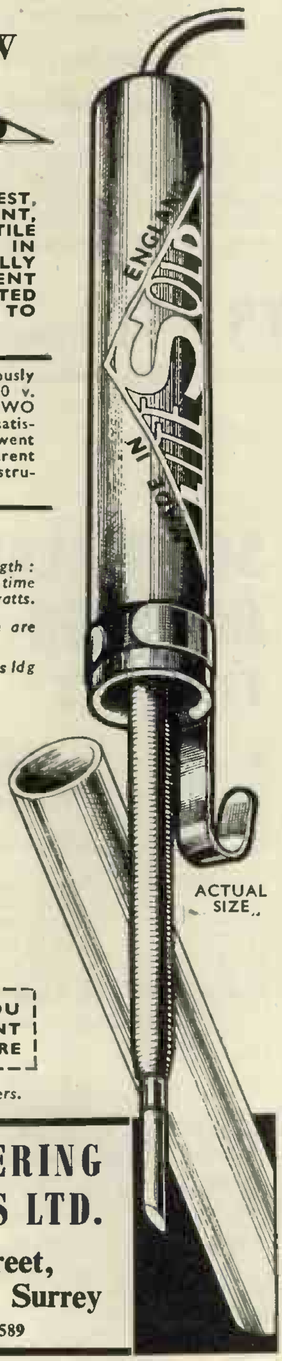

ACTUAL SIZE

SPECIFICATION

Weight (less flex) : ½ ounce. Length : 6 in. Bit dia. : ⅛ in. Heating time approx. : 1 minute. Loading : 12 watts.

Other models on the same principle are available as follows :—

3/16 dia. fixed or replaceable bit 23 watts ldg
¼ in. " " " 27 "
⅜ in. " " " 40 "

Supplied in standard voltage ranges from 6/7 v. to 230/50 v. complete with flex. Models for special voltages or low melting point solders supplied to order.

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⅛ in. Fixed bit model	19	6
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Safety shield for bench mntg.	5	0

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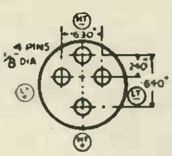
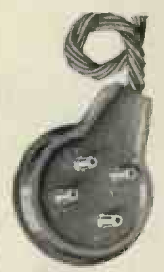
for cheaper radio listening



Plastic Plug Socket



BATTERY PLUG

The new Ever Ready plastic 4 pin battery plug has been specially designed to ensure correct and easy battery connections. Plugs are fitted with four staggered metal pins, also four coloured wires 18" in length. List Price 2/- complete. Suitable for use with BSS. 1766-1951.

This new Ever Ready Battery, combining a 90 volt high tension unit and a 1.5v low tension section, has been designed for use with the latest Ever Ready low consumption valves, type DK96, DF96, DAF96 and DL96, which use only half the filament current (25mA) of the older series valves (50mA).

A balanced service life of 300 hours is obtained when the high tension current is 10.5 mA at 90 volts and the low tension current 125 mA at 1.4 volts; the respective cut-off voltages being 40v and 1.0v on load.

The maximum battery dimensions are $7\frac{13}{16}'' \times 3\frac{7}{8}'' \times 4''$ and the weight is 5 lbs. 10 oz. **Price 16/-.**

EVER READY DRY BATTERIES FOR RADIOS TORCHES · HEARING AIDS · CYCLE LAMPS

Alcomax IV
incomparable for Rotating Magnets

Highly efficient rotating magnet system comprising Eclipse magnet between interleaving mild steel pole pieces.

Informative technical literature will be supplied on request.

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PERMANENT MAGNETS

★ Made by the makers of "Eclipse" Permanent Magnet Chucks

JAMES NEILL & CO. (SHEFFIELD) LTD.
SHEFFIELD 11 ENGLAND

M2

TWIN STABILISED POWER UNIT

Check these
Features
on EACH side :

- ✓ 180-350v. D.C. STABILISED, 180mA. RIPPLE : 8mV AT MAX. LOAD
- ✓ 400-450v. D.C. UNSTABILISED
- ✓ 170v. D.C. STABILISED NEGATIVE 2mA
- ✓ 4/6.3v. 3A A.C. EARTHY
- ✓ 4/6.3v. 3A A.C. ISOLATED

This is the only twin Power Unit on the market housed on one 19 in. panel. The two units can be used independently, in series, in parallel, or can be supplied with a self-balancing centre tapped source, one adjustment automatically sets equal positive and negative voltages for use with D.C. Amplifiers, etc.

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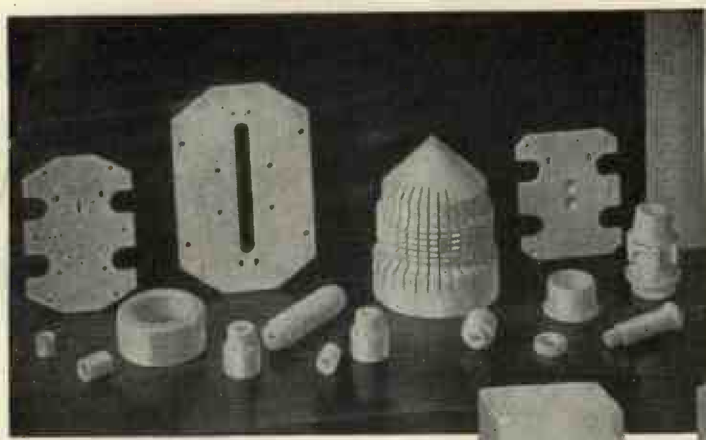

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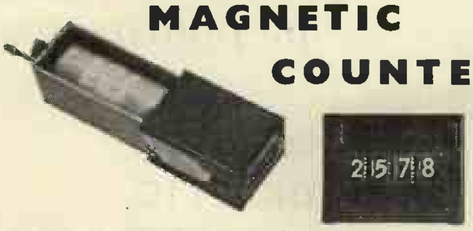

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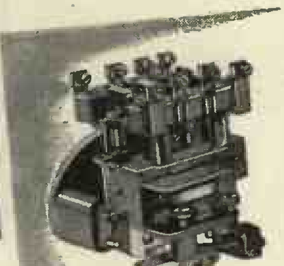

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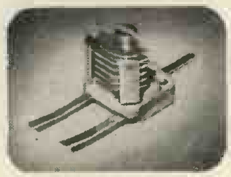

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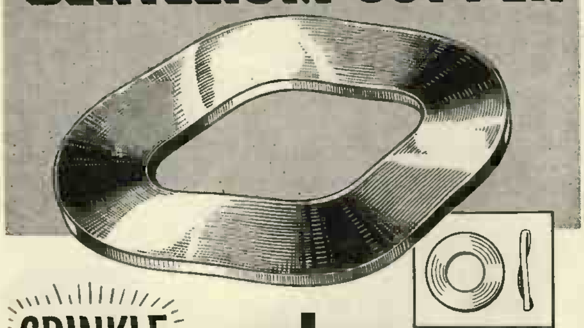

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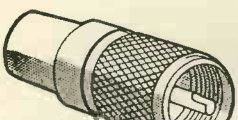

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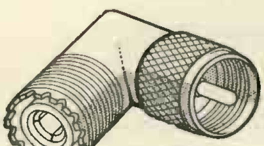

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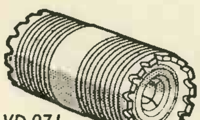

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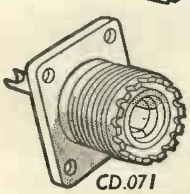
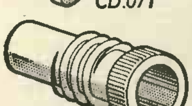


CD.071



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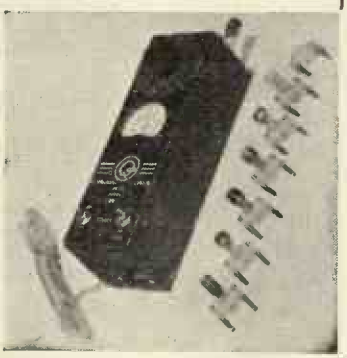

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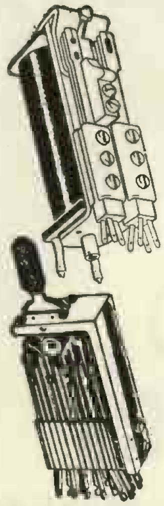

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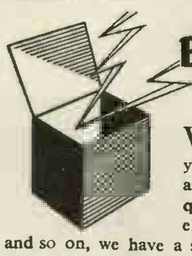

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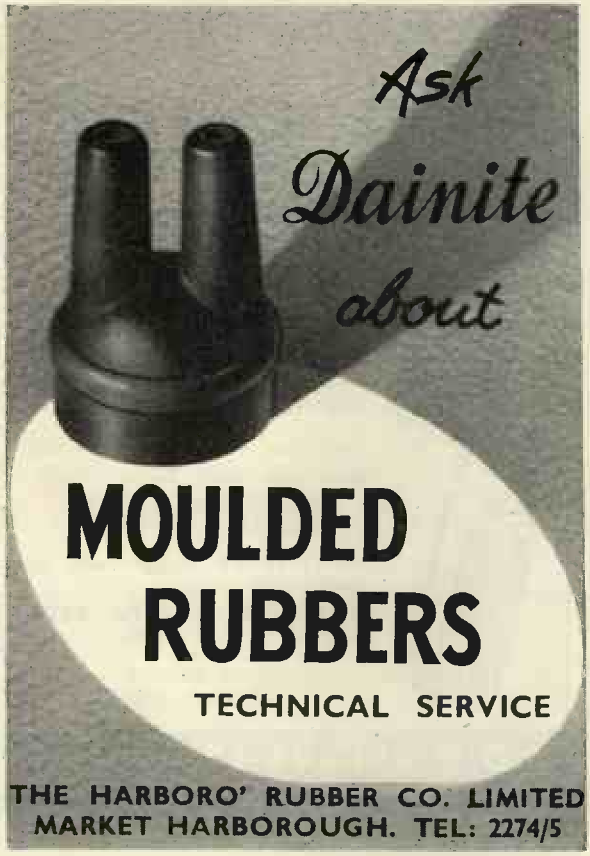

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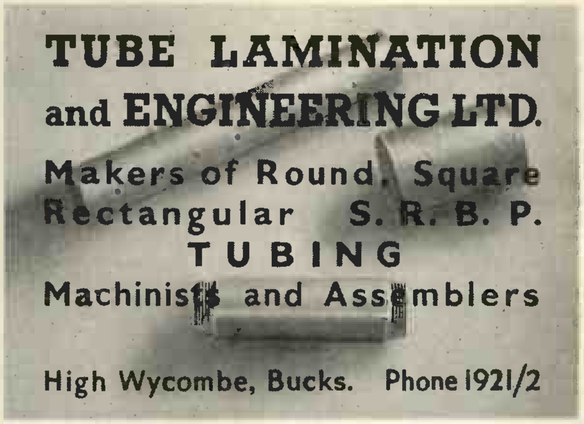

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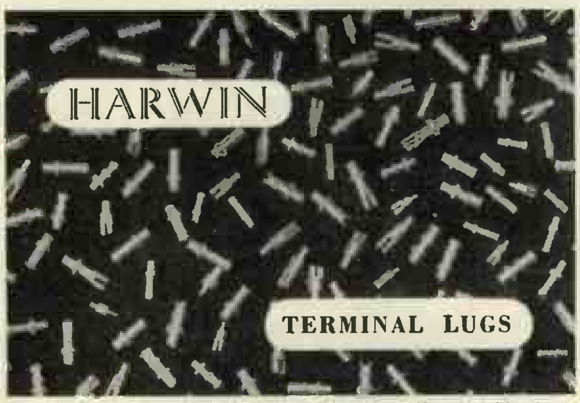

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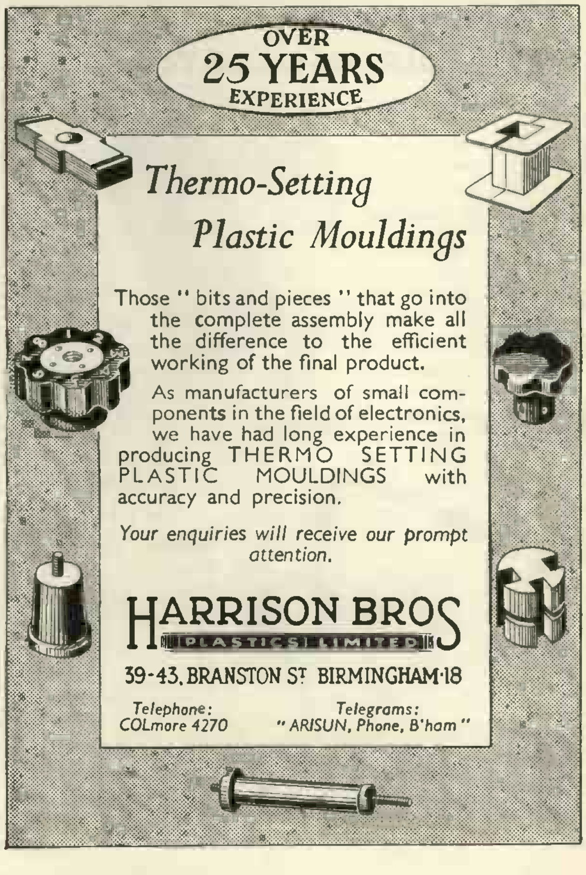

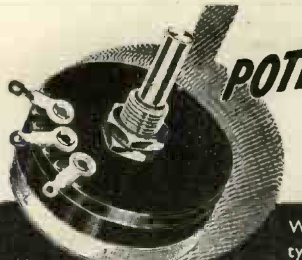

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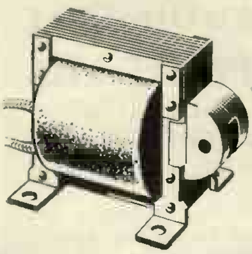

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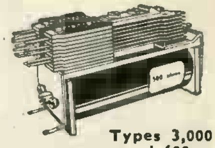

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