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Wireless World

Twenty-one Years

IN offering belated felicitations to the B.B.C. on the 21st anniversary of the establishment of the world's first high-definition television service, *Wireless World* has in mind in particular the work of the Engineering Division under the successive direction of Sir Noel Ashbridge and Sir Harold Bishop. Although we allow ourselves to be distracted occasionally by the efforts of the programme departments, it is with the millivolts per metre and the quality of the modulation that we are primarily concerned.

Already, the network of high-, medium- and low-power transmitters covers 98 per cent of the population; but the remaining 2 per cent, approximately a million souls, are not to be forgotten, for we learn that very low-power transmitters which will operate unattended are being developed to illuminate the remaining dark corners. Although local complaints are inevitable there can be no doubt that the country as a whole has been well served by the planning departments of the B.B.C.

Against the background of the early 30-line experiments by Baird which were broadcast by the B.B.C. on medium waves from 1930, the 405-line standard adopted in 1936 well merited the description "high-definition." It still does for the majority of viewers in this country, who own receivers of modest size and cost and who look at programmes in which the greater part of the "information" conveyed to the brain is essentially of a dynamic rather than a static nature. The need for a higher standard becomes apparent only when the programme people turn their cameras on still subjects containing detail finer than the resolution of the system (which includes the performance of the receiver) or when too large a screen is viewed at too short a distance. Few will dispute that the picture quality broadcast by the B.B.C. is still better than that of the majority of commercial receivers, which have to be produced at a price which the public will pay.

What of the future? It is not improbable that new techniques will eventually be evolved for the production, at prices we can afford to pay, of receivers with larger screens, higher definition and/or colour. When that day comes the B.B.C. will be ready to play its part, for it has already started an exploration of the potentialities in this country of Band V as a medium for the propagation of pictures of normal and higher definition; it is also broadcasting colour signals on Band I for the use of receiver manufacturers.

Pioneer Experiment

OUR congratulations and best thanks to the Russians for having placed a 1-watt transmitter in an orbit which traverses most of the civilized world, and on frequencies which were well chosen for revealing the effects of the ionosphere. Congratulations, also, to the radio receiving and radar tracking resources of this country for the speed and accuracy with which they were brought into action, and the ingenuity already displayed in extracting the maximum possible information from quickly improvised experiments.

Radio has given invaluable service to the physicists and astronomers in determining the motion of the satellites. It has also collected for itself a mass of data which is already yielding fresh knowledge of the constitution of the upper atmosphere and of the way in which radio waves are propagated. But because the life of the batteries has been relatively short, the transmitted frequencies restricted, and the trajectories have been at this time of year for the most part outside the ionosphere, much more remains to be done before the exploration of the fine structure of the ionosphere by extra-terrestrial waves reaches the same level as that attained by the ground ionospheric sounding stations of the world.

In many ways these first exciting days are reminiscent of the early experiments of Rutherford on atomic structure when far-reaching results were deduced from the patient observation of and subsequent cerebration on the scintillation of alpha particles on a zinc sulphide screen. Once again, it is the "scintillation" of the received signal strength and Doppler frequency shift which holds many of the secrets now being unravelled.

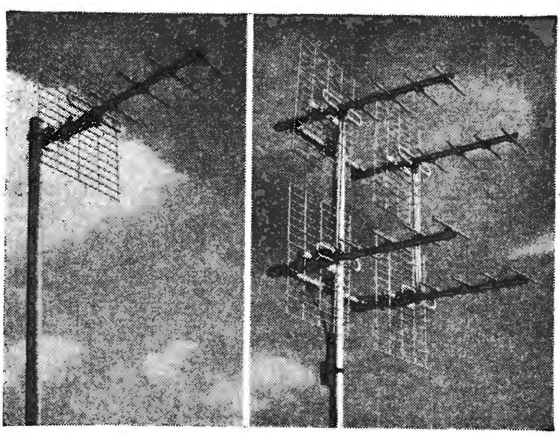
Band V Tests

U.H.F. TELEVISION BROADCASTS BY THE B.B.C.

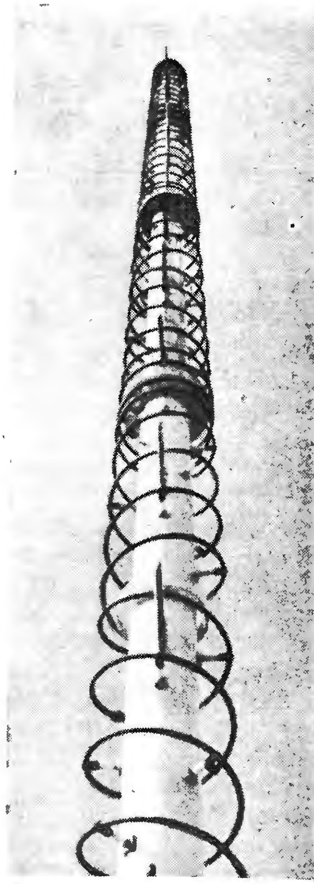
AT the request of the Television Advisory Committee the B.B.C. has started a further and more ambitious series of u.h.f. television experiments. Initially these tests, which began on November 9th, will employ the 405-line standard with vision on 654.25 Mc/s and sound on 650.75 Mc/s, but from about next April, after the transmitter has been modified, they will be on 625 lines with negative modulation and sound changed to 659.75 Mc/s, ±50 kc/s, f.m.

The B.B.C. has installed at the Crystal Palace a 10-kW (peak) u.h.f. vision transmitter and a 2.5-kW carrier power sound transmitter manufactured by E.M.I. The equipment is low-power modulated on both sound and vision channels and employs klystrons in both audio and video final stages. These klystrons use three external cavity resonators and operate as linear amplifiers with a power gain of approximately 100. They are driven by a modulated amplifier stage operating with a cathode modulated circuit. The output of the transmitters is combined in a circuit of the filter bridge type constructed in rectangular section waveguide. The combined output is then conveyed to the aerial by an elliptical (12in by 6in) waveguide. The elliptical waveguide is made of 99.5% aluminium in 12-ft lengths. At the top of the television mast the waveguide is transformed into a 5-in concentric feeder to take power to the four driving points of the helical aerial, the pole supporting the aerial forming the outer of the concentric feeder.

The helical aerial of ½in diameter copper rod comprises four bays, mounted one above the other on the same vertical axis, each having a linear height of five wavelengths. Each bay is fed at the centre, the helix being wound from the centre point of the bay in opposing directions to cancel the vertical component of radiation. The aerial has a power gain of 20 and after allowing for losses in the feeder and waveguide system, the effective radiated power of the vision signal is of the order of 125 kW (peak) in the horizontal plane.



Receiving aerials for u.h.f. television (Belling & Lee)



Surmounting the Crystal Palace mast the Band V helical aerial is about 700 feet above ground. There are 48 turns in all, each being approximately 2λ long

The transmitter is in use for several hours a day radiating the same programme as that being broadcast by the Band I transmitter in the same building. Later on, the pictures on 625 lines will be produced at Lime Grove from flying spot film-scanning equipment (supplied by Cinema - Television) and sent by a coaxial cable to the Crystal Palace.

Various types of receiver, representative both of designs that might become available at economic prices to the public and also of types at present unsuitable for domestic use, will be employed by the B.B.C., radio industry, Post Office, D.S.I.R., and I.T.A. to study the received pictures. The B.B.C. hopes that the information gained from these tests will throw light on the problems which would be encountered were it decided to provide television services in the u.h.f. bands and also the effects of a change of television standards for those bands.

It will be recalled that the B.B.C. started investigations into u.h.f. propagation some two years ago. These were concerned not only with service area tests but for the purpose of obtaining data on co-channel interference. For this purpose they employed Mullard transmitters, modulated by square-waves. They were installed at various television stations, and regular field-strength measurements were made over long periods at various locations, some as far away as the Shetland Islands.

The long-distance tests were followed in 1956 by a series to determine propagation conditions within a typical service area using a transmitter at the Crystal Palace, working into a Yagi aerial and radiating a peak power of 1 kW over a fairly narrow beam when modulated with square waves; pulse modulation was also used for some of the tests. The bearing of the aerial, which was at a height of 440ft, was changed from time to time so that field-strengths could be measured over the whole circle from Crystal Palace.

WORLD OF WIRELESS

"Scatter" Frequencies

SIX 400-kc/s bands have been allocated by the American Federal Communications Commission for ionospheric scatter transmissions. The lower frequency in each of these bands is 32.6, 34.6, 36.6, 46.6, 49.6 and 54 Mc/s, respectively. To avoid interference with American television stations, those frequencies which lie within the U.S. television channels will be used by scatter stations remote from the United States and its territories.

Some of these frequencies, of course, come within our TV channels and reference is made in the B.B.C.'s annual report to the interference (mainly in S.E. England) being caused by forward-scatter transmissions. Interference in the neighbourhood of the U.S. Air Force station at Kingston Blount, Oxford, was at one time very severe.

The possibility of more widespread use of forward scatter is viewed with some concern by the B.B.C., which stresses in it's report that television broadcasting bands should be protected from any such threatened interference.

Intermodulation Testing

AT an informal meeting of representatives of the leading British recording companies and pickup manufacturers, convened on the initiative of M. Minton, chief development engineer of Cosmocord, Ltd., the question of standards for expressing intermodulation distortion in pickups was discussed. At present no universally accepted method of testing has been established and comparison of published figures is often meaningless. After a general survey of the present position a working party was elected to investigate the problem in detail.

It has now been agreed that any further discussions of the working party shall be on a formal basis within the framework of R.E.C.M.F. Panel "N" (gramophone equipment).

Research Awards

THE Paul Instrument Fund Committee, set up by the Royal Society, Physical Society, Institute of Physics and I.E.E. "to receive applications . . . for grants for the design, construction and maintenance of novel, unusual or much improved types of physical instruments and apparatus for investigations in pure or applied physical science," have announced three awards.

Dr. D. Gabor, Mullard reader in electronics, Imperial College, receives £100, making £1,900 in all, for work on a new type of Wilson cloud chamber in the form of a resonant microwave cavity. Professor G. F. J. Garlick, professor of physics in the University of Hull, receives £2,700 to enable him to carry out studies of phosphors and photoconductors with a view to the development of solid-state light image amplifiers or converters. The third award, of £2,000, goes to Dr. H. H. Hopkins, senior lecturer in physics (technical optics), Imperial College, for the construction of a static scanning fibrescope.

B.B.C. Colour Tests

A SECOND series of test transmissions of colour television are being undertaken by the B.B.C. This new series of experimental transmissions, which began in October and will continue for about six months, are being radiated from the B.B.C.'s Crystal Palace station (Channel 1) outside the normal programme times.

The purpose of the tests, which are being conducted with a modified version of the American N.T.S.C. system, is:

(1) To provide a source of high-grade colour picture signals so as to permit colour receiver development work to continue,

(2) To enable further experience to be gained in the operation of the colour studio and colour transmitting equipment, and

(3) To obtain further knowledge of the compatibility provided by the particular system of colour transmission being tested.

Details of the somewhat involved cycle of transmission times are obtainable from the B.B.C.

Faraday Medallist

FOR his "outstanding contributions in the field of international communications and particularly in the development of long-distance, deep-sea telephone cables and their repeaters," Sir Gordon Radley, K.C.B., has been awarded the Faraday medal of the Institution of Electrical Engineers, of which he is the immediate past-president. Sir Gordon, who is the first engineer to be director general of the Post Office, has been in the G.P.O. since 1920 when he joined as a temporary inspector in the research branch. In 1944 he became the first holder of the office of controller of research and was successively deputy engineer-in-chief, e.-in-c., and deputy director general until he assumed his present position in 1955.

On his appointment in 1954 as deputy director general he retained, at his own request, technical responsibility for the British contribution to the transatlantic telephone cable with which he had been so closely associated.

Computer Standardization

ONE of the aims of the recently formed Data Processing Section of the Radio Communication and Electronic Engineering Association is the formulation of standards for computers, and to this end a number of working parties have been set up. One is concerned with nomenclature, another with tape standards for both analogue and digital computers, while yet another is studying information storage cores. The section, of which C. Metcalfe (E.M.I. Electronics) is chairman, includes 16 member-firms of the Association plus four other companies.

A growing number of associations and groups are being formed in this country to discuss data processing equipment and the R.C.E.E.A. Data Processing Section is investigating the possibility of forming a joint organization, through which information could be pooled.

As already announced, the R.C.E.E.A. is collaborating with the Office Appliance and Business Equipment Trades Association in organizing the first British Electronic Computer Exhibition and Convention, to be held at Olympia, London, from November 28th to December 4th next year.

The R.C.E.E.A. has also become one of the sponsoring organizations for the next Instruments, Electronics and Automation Exhibition to be held at Olympia from April 16th to 25th next year.

T.E.M.A.—The first awards in a competition introduced by the Telecommunication Engineering and Manufacturing Association for the best final-year apprentice of member-firms, were made at the Association's annual dinner on November 13th attended by some 270 members and guests. The recipients of the £25 awards in each of the three categories were:— D. V. Moreton (graduate in training) of A.T. & E.; R. L. Reid (student apprentice) of Ericsson; and B. A. Edwards (technician apprentice) of S.T.C. The T.E.M.A. dinner coincided with the publication of the Government white paper on changes in the telephone service including the introduction of electronic group routing and charging equipment (GRACE).

R.T.E.B.—A record number of candidates sat for this year's examinations for the servicing certificates issued by the Radio Trades Examination Board. Of the 1,117 taking the sound radio exam. 466 (42%) passed and 336 have to retake the practical test. Entrants for the television exam. totalled 237. Of these 106 (45%) passed and 48 have to retake the practical test. An analysis of the entrants shows that some 50% of the candidates were under 19 years of age, which may account for the examiners' view that approximately half the candidates lacked practical experience.

An Appointments Service for servicemen has been introduced by the R.T.E.B. It is available free to employers and the 2,500 holders of the Board's servicing certificates. Particulars are available from the Board at 9, Bedford Square, London, W.C.1.

Two research scholarships, valued at £435 per annum, have been awarded by the B.B.C. to graduates in electrical engineering giving them the opportunity to work for a higher degree. The subjects for research must be in those fields of telecommunications or physics which have an application to sound or television broadcasting. The recipients are J. B. Izatt, graduate of Aberdeen University, who will conduct his researches in the electrical engineering laboratories of Robert Gordon's Technical College, and W. A. G. Voss, who graduated at Queen Mary College (University of London), where he will continue his research work.

Medical Colour TV.—The American pharmaceutical firm, Smith Kline and French Laboratories, who have an establishment in this country and earlier this year demonstrated American closed-circuit colour television at St. Bartholomew's Hospital, London, have now ordered a mobile colour television unit from Marconi's. It will employ the anglicized 405-line N.T.S.C. system and will be placed at the free disposal of medical authorities for use at professional meetings. Both 21-inch direct-viewing colour monitors and medium-screen projectors will be used with the unit, which will also incorporate a monochrome channel.

Visit to Germany.—The Brit.I.R.E. proposes to arrange a party to visit factories, research laboratories and other radio establishments in Western Germany in the early summer of next year. The tour is planned to extend over about 10 days and in general the mornings would be devoted to technical visits and the afternoons to sight-seeing.

General Radio.—We are asked to point out that General Radio Co., of 9-10, Noel Street, London, W.1, whose advertisement appeared on page 92 of the November 1957 issue of *Wireless World* is not associated with the General Radio Co., of Cambridge, Massachusetts, U.S.A. Nor are they associated with Claude Lyons, Ltd., of Liverpool and Hoddesdon, Herts, who are the exclusive agents in the U.K. for the General Radio Company, of Cambridge, Mass., U.S.A.

Technical Hitch.—The opening of the I.T.A. transmitter at St. Hilary, Glam., originally planned for December 17th, has been postponed. An advanced design of aerial had been planned, but unforeseen technical difficulties have arisen necessitating further development work. Marconi's are therefore replacing it by a more conventional type giving similar coverage.

Test transmissions from the v.h.f. sound transmitter installed at the television station at Kirk o'Shotts, Central Scotland, began on November 15th. The station, which is due to come into regular service before the end of the year, will radiate horizontally-polarized transmissions on 89.9, 92.1 and 94.3 Mc/s with an e.r.p. of 120 kW.

Transatlantic trials of "Dectra," the long-range version of the Decca Navigator, are again under way. The tracking pattern is being produced from two of the stations in the East Newfoundland Decca chain and the ranging pattern by synchronized transmissions from stations in Newfoundland and Scotland. Tests on routine civil and military flights are being undertaken during these trials. Canada's fourth Decca Navigator chain, centred on Quebec, was brought into service on November 5th.

Brit.I.R.E.—In the Institution's report for the year ended March 31st the total membership is given as 5,568—an increase of 176 during the year, and of over 800 during the past three years.

Transatlantic Television.—A standard Pye 17-inch television receiver, fed from a rhombic aerial, was used in New York for the reception of B.B.C. television transmissions direct from London on November 1st. The set was lent to Press Wireless, Inc., and was used at their receiving station at Baldwin, Long Island.

TV on Tape.—For his achievements in the development of a practical video tape recorder, Charles P. Ginsburg, manager of advanced videotape development in the Ampex Corporation, California, has been awarded the David Sarnoff Gold Medal by the American Society of Motion Picture & Television Engineers.

Soviet Colour Television.—Three systems of colour television are now being tested in Moscow and Leningrad, according to *Soviet News*, to determine which one to adopt in the Union. At present there are approximately two million monochrome receivers in use in the U.S.S.R.

Transistor Circuit Techniques.—A course of ten evening lectures on transistor circuit techniques is to be held on successive Tuesdays from January 21st at the Medway College of Technology, Maidstone Road, Chatham, Kent.

"**Electronics in Industry**" is the title of a five-day course organized by the factory department of the Ministry of Labour, to be held at Burton in Wirrall, Cheshire, from January 20th to 24th. The fee is £6, including tuition and residence, for people from adjoining areas, but £7 for others. Applications should be sent to J. B. Newton, the warden, Burton Manor Residential College for Adult Education, Burton in Wirrall, Cheshire.

Radio transmissions of particular interest to yachtsmen, and lists of coast radio stations and radio beacons, are given in the 52-page reference section of the *Yachting World* Diary for 1958, which includes all the day-today information the yachtsman requires. The Diary costs 10s in leather binding or 6s 6d in waterproof Rexine.

"Induction" Licence.—The period covered by the £2 licence for "inductive" paging systems recently introduced by the Post Office is five years, not one year as stated on page 518 of our last issue. The number of sending and receiving "stations" covered by the licence is unlimited.

Receiving Licences.—An increase during September of 66,978 in the number of combined television and sound licences in the United Kingdom brought the total to 7,398,185. This figure, together with the 6,945,178 licences for domestic sound receivers and 324,078 for car radio, brings the overall total at the end of September to 14,667,441—a decrease of nearly 18,000 during the month.

A two-day conference on band theory of metals and the structure of the Fermi surface has been organized by the Physical Society. It will be held at Imperial College, London, on December 19th and 20th. The conference fee for non-members is one guinea. Applications for programmes and registration forms should be addressed to Miss Miles at the Society's headquarters, 1, Lowther Gardens, Prince Consort Road, London, S.W.7.

Next Year's National Radio Show has been fixed for August 27th to September 6th with a preview on the 26th. This will be the 25th national show and will again be held at Earls Court, London.

WHAT THEY SAY

Visionary.—"I sometimes think that one or two dealers must really believe the old saying, 'without vision the people perish,' because they don't seem to stock much in the way of non-vision receivers!"—*Arthur Glover, Murphy Distribution Manager.*

"What's in a Name?"—"Radio communications, in the broad sense that includes broadcasting and aids to navigation, is the technology for which the I.R.E. was founded. But today only a minority of the members of I.R.E. would claim that 'radio engineer' best describes their calling. In fact, the word 'radio' does not appear once among the names of the I.R.E. Professional Groups, and only one-half of the Group organizations have any direct interest in radio frequency techniques as such."—*Donald G. Fink, Editor, "Proceedings of the Institute of Radio Engineers."*

Personalities

Rear-Admiral Sir Philip Clarke, R.N. (retd.), K.B.E., C.B., D.S.O., immediate past-president of the British Institution of Radio Engineers, was recently presented with a silver cigarette box bearing the Institution's coat-of-arms in commemoration of his presidency from 1954 to 1956. Sir Philip was director of the Naval Electrical Department at the Admiralty from 1951 to 1955.

Sir Harold Bishop, C.B.E., director of engineering in the B.B.C., has accepted the invitation from the Television Society to become a vice-president. Sir Harold has been with the B.B.C. since 1923, and was chief engineer for nine years before he succeeded Sir Noel Ashbridge in 1952.

Sir Ivone Kirkpatrick, G.C.B., G.C.M.G., has succeeded **Sir Kenneth Clark,** K.C.B., as chairman of the Independent Television Authority. Sir Ivone, whose appointment by the P.M.G. is for five years, retired from the Foreign Office last February. He is 60. At the beginning of the war he was director of the foreign division of the Ministry of Information, and in 1941 became controller of the B.B.C.'s European Service.

Sir Harry Railing, D.Eng., Hon.M.I.E.E., has relinquished the position of chairman and joint managing director of the General Electric Company, which he joined in 1905 to take charge of the test department and laboratories at Witton Engineering Works. Sir Harry, who received a knighthood in the New Year's honours of 1944, was trained as an electrical engineer on the continent, where he received his degree, and then spent some time in the U.S.A. before joining the G.E.C. He is succeeded by **Leslie Gamage,** M.C., M.A., who joined the company as assistant secretary in 1919.

R. N. Fitton, who 28 years ago founded the original company manufacturing Ambassador receivers, has relinquished the managing directorship of Ambassador Radio & Television, Ltd., and is succeeded by **Denis Robinson,** who is also managing director of E-V, Ltd. Both companies are in the Camp Bird Group.

Eric E. Pratt has been appointed commercial manager in the electronics and equipment group of the Plessey Company. He was at one time in the equipment division of Mullard and more recently was sales manager of Airtech, Ltd.

James Reekie, B.Sc., Ph.D., A.M.I.E.E., F.R.S.E., appointed chief engineer of Semiconductors, Ltd., the recently formed Plessey - Philco company, has been in Canada for the past 12 years. Dr. Reekie was for some time professor of physics at the University of Toronto and later head of the department of physics at the Royal Military College of Canada, but immediately prior to returning to this country he was research director in semiconductors and solid state physics for the Northern Electric Company, Montreal.

Alan Lee, M.A., M.I.E.E., is appointed to the newly created chair of electrical engineering (radar and telecommunications) at the Royal Military College of Science, Shrivenham, Wilts., where he has been head of the radar and telecommunications branch since 1941. Professor Lee, who is 50, joined the college in 1935, having previously spent a short time in research in industry and teaching at the R.A.F. electrical wireless school at Cranwell.

Arthur Charlesby, D.Sc., Ph.D., A.R.C.S., F.Inst.P., is appointed to the new chair of physics at the Royal Military College of Science. After a period in the scientific research department at the Ministry of Aircraft Production he served with the R.A.F. until 1945 and from 1949 to 1954 was a principal scientific officer at A.E.R.E., Harwell. For the past two years Professor Charlesby, who is 41, has been head of the radiation department of Tube Investments Research Laboratories.

Robin W. Addie, M.A., who was for some years technical commercial manager of Philips and for the past 18 months has been assistant commercial manager, has left the firm and joined E.M.I. Electronics as export manager. He graduated from Cambridge in 1939 with a degree in engineering and joined Philips in 1946. He is the chairman of the Radio Industry Council's exhibition technical committee and has for the past few years been largely responsible for the sound and television relay installations at the National Radio Show.

K. S. Brown, the new president of the Institution of Radio Engineers (Australia), spent five years in England after graduating Bachelor of Electrical Engineering at Melbourne University. During his stay in this country he spent two years with the G.E.C. at Coventry and three years with S.T.C., where he was engaged on radio and line transmission equipment. He returned to Australia in 1939 to establish a valve division in the S.T.C. factory at Sydney and he is now manager of the electronics division which absorbed the valve division.

Major C. Collaro, O.B.E., has resigned his position as chairman and managing director of Collaro, Ltd., owing to ill-health, but will continue to be available to the company on technical matters. **Henry Roughton** succeeds him as managing director and **E. B. Urietti,** previously works manager, has joined the board.

F. R. W. Strafford, M.I.E.E., has been exclusively retained as technical consultant for aerial and aerial components by Kimber-Allen, Ltd., of Myron Works, London, S.E.13. Mr. Strafford will continue his technical practice in other radio and electronics spheres.

W. Woolfenden, engineer-in-charge of the Croydon I.T.A. station since its opening in 1955, has been appointed e.-in-c. of the Authority's St. Hilary transmitter. He was with the B.B.C. for eight years before joining the I.T.A. and was an R.A.F. radar officer during the war. He is succeeded at Croydon by **G. E. Tagholm,** B.Sc.(Eng.), who was on the B.B.C.'s Alexandra Palace staff before joining the Authority.

A. J. Solomon, executive engineer at the Post Office receiving station at Ongar, Essex, since 1955, succeeds **G. K. Fagg,** who retired on August 30th, as manager/engineer of the Post Office radio station at Bodmin, Cornwall. Mr. Fagg joined Marconi's as a radio operator in 1912 and in 1921 went to the company's research department. He subsequently joined Cable & Wireless, transferring to the Post Office in 1950 when C. & W.'s services in the U.K. were integrated with those of the G.P.O. Mr. Solomon is also an ex-Marconi man. He was for some time in the commercial receiver development section at Chelmsford.

A. T. Black, C.B.E., has left the Ministry of Supply, where he was director of electronics production (munitions), and has joined Pena Copper Mines, Ltd., where he will direct the group's electronics division. It will be recalled that Pena recently acquired Peto Scott Electrical Instruments and Cosmocord.

H. W. Shipton, A.M.Brit.I.R.E., who for some years has been electronics development engineer at the Burden Neurological Institute, Bristol, has accepted the position as research associate in medical electronics in the State University of Iowa, U.S.A. He is probably best known for his work on toposcopic display systems for electro-encephalography. His duties at Bristol will in future be shared by Dr. R. Cooper and W. J. Warren.

M. W. S. Barlow, M.A., A.M.Brit.I.R.E. (G3CVO), who was a founder member and secretary of the British Amateur Television Club and has contributed to *Wireless World* on amateur television topics, has left Marconi's at Chelmsford, where he has been a development engineer for the past four or five years, to take up an appointment with the Canadian Marconi Company.

Baron C. de Beer, who has been associated with the Rediffusion group of companies for some years, being until recently assistant chief engineer of the Jamaica Broadcasting Company (a member of the group), has joined the Rocke International Corporation, of New York, as chief engineer (broadcast and communications). For ten years prior to joining Rediffusion he was a signals officer in the R.A.F.

N. P. White, recently appointed manager of the components division of A. C. Cossor, Ltd., joined the company in 1939 and has successively held the positions of manager of the methods department and chief production engineer.

OUR AUTHORS

R. J. Hitchcock, M.A., A.M.I.E.E., author of the article on page 599, joined Cable & Wireless in 1948, where he was initially engaged on radio-frequency allocation work and represented the company at international conferences including the Extraordinary Administrative Radio Conference in Geneva in 1951. He is now in charge of a section of the engineer-in-chief's department responsible for the design of aerials, radio propagation and radio circuit performance studies, prediction of optimum usable frequencies and other radio frequency matters such as interference, etc. He is a member of the U.K. study groups of the C.C.I.R. dealing with ionospheric, tropospheric and ground-wave propagation.

Francis Oakes, A.M.I.E.E., A.M.Brit.I.R.E., M.Inst.E., and **E. W. Lawson,** A.M.I.E.E., who contribute the article in this issue on a transistorized galvanometer, have previously collaborated to write for *Wireless World*. They are both with the Ferguson Radio Corporation, where Mr. Oakes (a frequent contributor to *Wireless World*) is in charge of transistor applications research and Mr. Lawson is in charge of the standard laboratory at Enfield. Mr. Oakes, who came to this country from Austria, was for some time assistant chief of the electronics laboratory of the Morgan Crucible Company before joining Ferguson. Mr. Lawson, following service with the Ministry of Aircraft Production during the war, was in charge of quality control at Plessey until joining Ferguson.

G. J. Phillips, M.A., Ph.D., B.Sc., A.M.I.E.E., who writes in this issue on discriminator bandwidth in f.m. broadcast receivers, joined the B.B.C. engineering division in 1951 after post-graduate work on ionospheric measurements at the Cavendish Laboratory, Cambridge. Dr. Phillips has been engaged on B.B.C. transmitting aerial design and is now in charge of receiver and measurement work in the B.B.C. research department at Kingswood Warren, Surrey.

Sqn. Ldr. G. de Visme, B.Sc., Grad.I.E.E., contributor of the article on a phase indicator, took his degree at London University in 1942 and then spent four years in R.E.M.E. After demobilization he worked for two and a half years in the G.E.C. research laboratories, and then in 1950 joined the education branch of the R.A.F. He is now instructor in electronics at the R.A.F. Technical College. Since joining the air force he has obtained a diploma in electronics from Southampton University.

OBITUARY

James P. McKenzie, M.C., A.M.I.E.E., chairman and managing director of Sifam Electrical Instrument Co., Ltd., died on October 9th at the age of 68. After the first world war he was for a short time with Elwell Radio before joining Standard Telephones & Cables. He later became sole British agent for the French company Société Industrielle pour la Fabrication D'Appareils de Mésure and when in 1927 tariffs made the import of instruments prohibitive he formed the present Sifam company using the name by agreement with the French company.

James G. Yates, who since 1946 has been a lecturer in the Department of Engineering at Cambridge University, where he did "outstanding work in building up the teaching of electronics," died on November 1st, aged 42. A graduate of Trinity College, Dublin, he joined the Radar Research and Development Establishment at Christchurch in 1940, where he worked throughout the war.

Lionel W. Sansum, secretary and director of A. F. Bulgin & Co. for over 30 years, died on October 15th,

F.M. Discriminator Bandwidth

ITS SIGNIFICANCE IN HIGH-QUALITY BROADCAST RECEPTION

By ***G. J. PHILLIPS,*** ***M.A., Ph.D., B.Sc., A.M.I.E.E.****

FROM time to time in the technical literature the advantages have been discussed of a f.m. discriminator which remains linear over a bandwidth very much in excess of the deviation range of the signal being received[1]. Some of these articles give the impression that wide-band discriminators offer a clear advantage in all f.m. applications, and can give a useful reduction of many types of interference. It is the purpose of this article not only to discuss those aspects in which better performance can be achieved by this means, but to review all aspects of the performance in relation to the requirements of a broadcasting service. Interest in wide-band discriminators was at one time aroused by the possible use of f.m. for long distance short-wave communication[2], but it is more convenient for discussion to consider first the interference that can arise between two separate f.m. transmitters operating on the same channel—i.e., co-channel interference.

* B.B.C. Engineering Research Department.
[1] See for example "F.M. Receiver Design," by Lawrence W. Johnson. *Wireless World*, October 1956, p. 497.
[2] Arguimbau, L.B., and Granlund, J., "Sky-Wave F-M Receiver." *Electronics*, December 1949, p. 101.

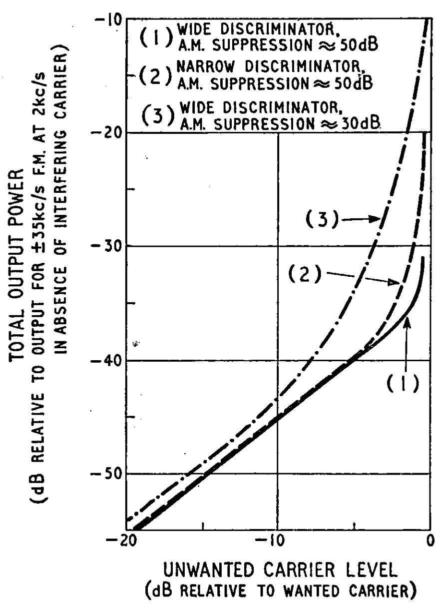


Fig. 1. Power output due to co-channel interference as a function of carrier ratio. In taking these curves the wanted carrier was unmodulated, and the interfering carrier was modulated with ± 35 kc/s deviation at 2 kc/s. An aural weighting network was used in front of the power meter. The narrow discriminator with approximately 30 dB a.m. suppression ratio gave a curve practically identical with curve (3).

Co-channel Interference.—We shall suppose, in discussing the interference heard when listening to the stronger of two co-channel transmissions, that two different programmes are being radiated. On any given receiver, assuming the signal strength is adequate, the interference will depend on the level of the interfering carrier relative to the wanted carrier. Before going any further we should have some idea of the kind of noises that will mar the wanted programme. There are two distinct forms of interference. First, the unwanted modulation may be recognizable in the background and secondly, there may be a characteristic "swishing" noise.

The so-called capture effect is concerned with the first type of interference only. If the unwanted carrier is equal in strength to the wanted carrier the two programmes will be equally audible, but as the unwanted carrier is reduced the unwanted modulation rapidly becomes fainter. The ratio of carrier levels at which it just becomes inaudible is termed the capture ratio. Now it is sometimes assumed that interference troubles are over at this stage, but this, alas, is not so. There remains a noise which (except when there happens to be a pause in both programmes) might be described as a "swishing" or "fizzing" noise. This second type of interference unfortunately remains audible for a much smaller unwanted carrier level than that existing at the "capture" stage, and arises from a beat effect between the two f.m. signals. Both amplitude and phase modulation of the wanted carrier result from the addition of a weaker carrier of a slightly different frequency, but interference is normally reproduced in a f.m. receiver by virtue of the phase modulation component. In the absence of modulation on either carrier a steady beat note corresponding to the transmitter frequency difference is expected—though in practice some warbling of the note will occur. But if either or both of the carriers are deviated the swishing noise is produced as the frequency difference passes rapidly through the audible range.

The dependence of the total interference power on the carrier ratio is shown by the experimental curves in Fig. 1. They all refer to measurements made with a special receiver in which the bandwidth before the limiter was kept at ± 100 kc/s. Limiting was achieved in two stages, giving a very good degree of a.m. suppression. A Foster-Seeley discriminator was used which was linear over a bandwidth of at least ± 1 Mc/s, but, in order to obtain precise discriminator bandwidths, either a wide (± 1 Mc/s) or a narrow (± 120 kc/s) band-pass filter could be interposed between the limiter and the Foster-Seeley circuit. Two signal generators were used, the outputs of both being fed to the receiver; an unmodulated carrier was used to represent the wanted transmission and a carrier with ± 35 kc/s f.m. at 2 kc/s was varied in level to represent a modulated interfering signal. Under these conditions the receiver output power represents the interference and has been plotted against the level of the unwanted carrier. The two alternative discriminator bandwidths were used with the full limiting maintained, curves (1) and (2). In addition, the wide-band condition was measured with the limiting efficiency reduced to that of a fairly good domestic receiver for f.m. reception, curve (3).

It is seen that in all cases there is at first a straight-line region where the interference is proportional to the unwanted carrier level; this occurs where the latter is relatively small and only the "swishing" noise is present. Curve (1) shows that, given good limiting and a discriminator of ± 1 Mc/s bandwidth, the interference remains proportional to the unwanted carrier level until a carrier ratio of about 2 dB is reached. At this point breakthrough of the unwanted modulation begins to reinforce the other interference and the curve begins to rise more steeply; this is the "capture" threshold. If the discriminator is narrowed to ± 120 kc/s this threshold occurs at a lower level of the unwanted carrier as shown by the earlier rise of curve (2). The effect of reduced limiting efficiency, as shown by curve (3) for the wider discriminator, is two-fold: (a) earlier onset of the breakthrough of unwanted modulation and (b) increased interference at all carrier ratios. The curve for the narrow-band discriminator with reduced limiting is not shown here—it was found to coincide within 1 dB with that for the wider discriminator; no significant difference between the discriminators was apparent, due presumably to the restriction in performance now imposed by the limiter. In all cases the graphs continue as straight lines at 45° for unwanted carrier levels lower than those plotted in Fig. 1, until receiver noise in the output becomes comparable with the power being measured.

In a communication system we wish to make the best of the situation even when the carriers are nearly equal. It is then worth while paying considerable attention to limiting efficiency. Then, but only then, a wider discriminator can be used to gain some further advantage. On the other hand, for a broadcasting service a 20 dB carrier ratio is not sufficient to give reasonably interference-free reception. This may seem an incredible statement when Fig. 1 shows that a signal-to-interference ratio of some 55 dB occurs for a 20 dB carrier ratio. But that is the startling thing revealed by experiments on co-channel interference—the small amount of it, in terms of audio power, that can spoil reproduction, particularly of music; this is true whether or not the modulation on the unwanted carrier corresponds to the same programme. Now Fig. 1 shows that for an unwanted carrier at or below the -20 dB level the various arrangements differ in performance by no more than 1 dB. This includes a narrow-band discriminator with an a.m. suppression ratio[3] of about 30 dB, since it performs substantially as shown by curve (3).

Should the a.m. suppression ratio be less than 30 dB the story is rather different. Extra interference is produced for all carrier ratios. This is because, when an audio-frequency beat is produced, it is not only the phase modulation of the resultant of the two carriers that matters; amplitude modulation also can contribute appreciably to the interference at the receiver output.

Multi-path Distortion.—Another phenomenon closely related to co-channel interference is distortion arising from multi-path propagation. With a very large path difference, in fact, the physical conditions are virtually the same as for co-channel interference when there are two stations some distance apart broadcasting the same programme. Fortunately, this has been anticipated in f.m. station planning since (without allowing for any further advantage possible by a directional aerial) it is intended to secure a carrier ratio of at least 20 dB between co-channel stations for 99% of the time when in the appropriate service area. It is not surprising, therefore, to find that a delayed signal some 20 dB below the direct signal causes distortion when the path difference is greater than about 5 miles. This distortion is particularly noticeable on piano music. It changes somewhat in character as the path difference changes from, say, 20 miles (when it takes the form of a fizzy noise like co-channel interference) down to 5 miles (when it becomes almost indistinguishable from the effect of something loose in the loudspeaker). It should be added that the shorter the path difference (below about 20 miles) the larger the delayed signal that can be tolerated, so that reflections with only 1 mile or less path-difference must exceed a half of the direct signal in amplitude to give appreciable distortion. This is because the frequency of difference between the direct and delayed signals arriving at the receiver can no longer be very great, and so a frequency high compared with that of the modulation cannot be produced. This subject has been discussed more fully by M. G. Scroggie in a previous issue[4].

Regarding co-channel interference and multi-path distortion, experience has shown an a.m. suppression ratio of 35 dB to be a good target to aim at in receiver design; given this, receivers with discriminators of ordinary bandwidth will not *under conditions applicable to broadcasting* show appreciably greater interference than a more elaborate receiver. Any interference will be predominantly that corresponding to the audio component of the phase modulation of the resultant signal. Further improvements in difficult situations must rely on suitable orientation of a directional receiving aerial.

Impulsive Interference.—Turning now to impulsive interference, Fig. 2 gives the result of measurements using the experimental receiver with full limiting. Short impulses of controllable amplitude were applied to the input of the receiver at a constant rate, a fairly high rate (2,500 per second) being used to facilitate measurement of the interference when using impulses of small amplitude. They were applied in the presence of a f.m. carrier to which the receiver was tuned. The output power due to the

[3] The a.m. suppression ratio used here is defined as the ratio of the output due to the f.m. to that due to the a.m. when a signal having 40% a.m. at 2,000 c/s simultaneously with ± 30 kc/s (40% of 75 kc/s) f.m. at 100 c/s is fed to the receiver. Its measurement has been discussed by G. G. Johnstone in the August 1957 issue of *Wireless World*, p. 378.

[4] See "F.M. Multi-Path Distortion," *Wireless World*, December 1956, p. 578.

impulsive interference has been plotted against the amplitude of the impulses.

The difference in performance of the two discriminators is small, being no more than a few decibels at all levels of interference. Moreover, for repetition rates met in practice, the amount of interference heard when the impulse amplitude is less than the peak carrier amplitude is not serious. The region of importance is therefore when the impulses are greater than the threshold value marked in Fig. 2, and there the wide-band discriminator gives slightly more interference than the discriminator of conventional bandwidth. The effect of reducing the a.m. suppression ratio is not shown here; a moderate reduction merely gives a more gradual step at the threshold. Generalizations in the case of impulsive interference are difficult to make since factors other than discriminator bandwidth and a.m. suppression

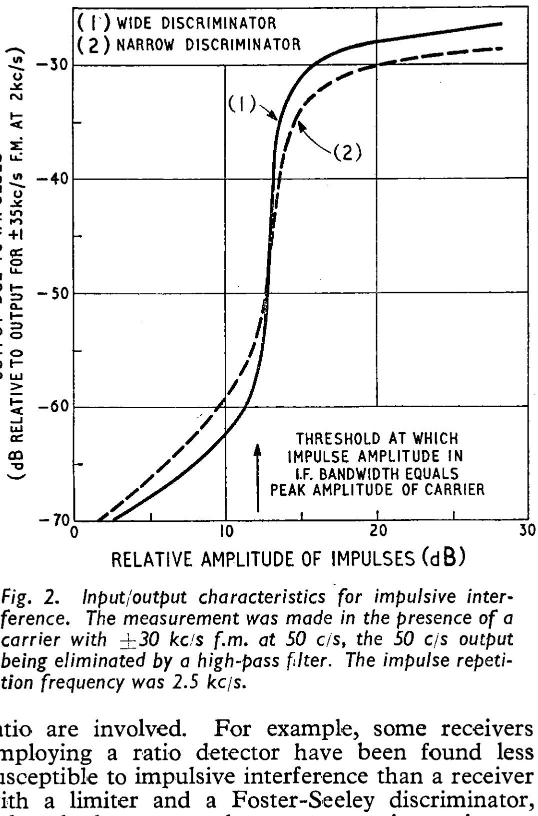


Fig. 2. Input/output characteristics for impulsive interference. The measurement was made in the presence of a carrier with ±30 kc/s f.m. at 50 c/s, the 50 c/s output being eliminated by a high-pass filter. The impulse repetition frequency was 2.5 kc/s.

ratio are involved. For example, some receivers employing a ratio detector have been found less susceptible to impulsive interference than a receiver with a limiter and a Foster-Seeley discriminator, although the measured a.m. suppression ratio was inferior in the ratio detector receivers. A limiter before a ratio detector does not necessarily lose this advantage under impulsive interference conditions, and can improve the performance with other forms of interference.

Adjacent-channel Interference.—Adjacent-channel interference (due to a transmission with a carrier frequency differing by 200 kc/s from the frequency of the wanted carrier in the case of broadcasting) can of course always be reduced by improvements in the i.f. selectivity. The selectivity should be sufficient to ensure that the interfering carrier is fairly small compared with the wanted carrier at the stage where limiting takes place. Then a good limiter and a symmetrical two-diode discriminator can in theory provide good protection. This is because the output of the ideal limiter, being purely f.m., has sideband amplitudes which are symmetrical about the carrier frequency (principally two equal components at ±200 kc/s relative to the carrier in the case being considered). With an ordinary Foster-Seeley discriminator one diode is mainly sensitive to the component 200 kc/s higher than the wanted carrier in frequency, and the other to the component 200 kc/s lower. The contributions of the diode circuits to the final output are of opposite polarity. With no modulation on the wanted carrier the extra outputs of the diodes due to interference should, by symmetry, be equal in magnitude and therefore cancel. This will apply even when the interfering carrier varies in frequency or amplitude due to modulation. With deviation of the *wanted* carrier frequency the situation is not so straightforward, and cancellation will not generally be complete.

In practice we may say that besides i.f. selectivity, various departures from the ideal both in limiter performance and in symmetry of the discriminator play a part in adjacent channel protection. More experimental work is needed to be able to decide how important these are. There is as yet no evidence that the use of a wide-band discriminator will help with this form of interference; in fact its greater sensitivity to ±200 kc/s components may result in more interference for a given degree of symmetry. There would seem to be a good case, however, for a limiter which is efficient in suppressing amplitude fluctuations up to a few hundred kilocycles per second. This will make the best of available selectivity though, as stated above, an improvement in the i.f. selectivity curve is always capable of giving less interference. A *slope* of the amplitude response curve of the i.f. stages at 200 kc/s from the carrier frequency can play a part by causing the effective strength of the interfering carrier to vary as it is deviated by modulation; the *shape* of the response curve as well as the attenuation at the adjacent channel frequency must therefore be considered.

Conclusions.—A wide-band discriminator reduces co-channel interference only when the unwanted carrier is comparable in strength with the wanted carrier. This means that in conditions where the improvement due to the wide-band discriminator is becoming important the background interference is then too high for a satisfactory broadcasting service. Expressed in another way, a significant improvement using a wide-band discriminator is achieved only when the wanted-to-unwanted carrier ratio is less than about 6 dB. But it is not until an interfering transmission or a long-delayed echo is more than 20 dB below the wanted signal that reproduction becomes sufficiently free from background noise or distortion to be acceptable for a broadcasting service; in certain critical cases a carrier ratio greater than 30 dB is needed to avoid noticeable effects. Moreover the limited improvement mentioned above can be achieved only at the expense of considerable complication in the receiver; for optimum performance of a wide-band discriminator the a.m. suppression ratio must be at least 50 dB.

On the other hand if conditions are restricted to those encountered in broadcast reception a narrow-band discriminator and an a.m. suppression ratio of 35 dB are generally satisfactory, and no significant improvement is to be obtained from a wide-band discriminator and increased a.m. suppression. A practical point worth noting here is that a.m. suppression may vary considerably with small changes in tuning in the case of some receivers. A receiver should therefore be designed to ensure that the suggested a.m. suppression ratio is reached or exceeded when tuned under normal conditions, since it is seldom practicable to tune for best results in the presence of co-channel interference or multi-path distortion.

Regarding other forms of interference, several aspects of receiver design are usually involved and the importance of some of these are still being studied. But there does not appear to be any clear advantage in using a wide-band discriminator and in one case at least (impulsive interference) its performance appears, if anything, to be poorer than that of more conventional arrangements.

I am grateful to various colleagues for their helpful discussion, in particular Mr. J. G. Spencer who also made available the experimental results which form the basis of the curves of Figs. 1 and 2.

ИСКУССТВЕННЫЕ СПУТНИКИ ЗЕМЛИ | ARTIFICIAL SATELLITES OF THE EARTH

Observations by Radio on the First Transmitters Beyond the Ionosphere

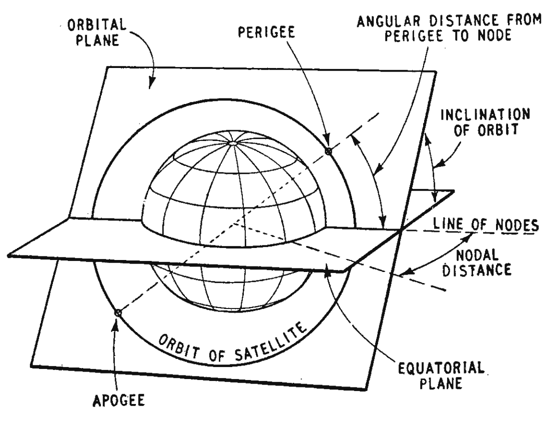
THERE was great excitement in the world of radio on October 5 when it was learnt that the Russians had launched their first satellite. In spite of much previous discussion on the reception of satellite signals*, the actual event took everyone by surprise. Observing stations were hastily improvised from existing equipment by amateurs and professionals alike. The B.B.C. used their listening station at Tatsfield, the D.S.I.R. their radio research establishment at Slough, and the G.P.O. their measuring stations at Baldock and Banbury. At the same time the radio astronomers at Cambridge and Jodrell Bank worked furiously to rig up equipment for precise position-finding measurements on the actual track of the satellite, while similar measurements were started immediately by the Royal Aircraft Establishment, Farnborough, and at Malvern by the Royal Radar Establishment. Between these official organizations and the many amateurs who made observations were bodies like the British Astronomical Association, whose Radio Section took recordings of the signals at their small station at Clacton.

Nobody in this country was prepared for the use of 20Mc/s and 40Mc/s as the transmission frequencies because it was expected that the American satellite, using 108Mc/s, would be the first to be launched. This state of unpreparedness should never have existed, however, for the frequencies were published in the June, 1957, issue of the Russian journal *Radio,* which is available in this country, and were officially notified to the Royal Society in the following August. The June issue of *Radio* contained two articles (from the first of which our title is reproduced) mainly giving advice to amateurs for observing the satellite. The first begins:—

"During the course of the International Geophysical Year it is intended in the U.S.S.R. to launch a number of artificial satellites of the earth, equipped with radio-transmitting apparatus. Radio observers of the signals from these satellites will make it possible to obtain fresh data regarding the structure of the ionosphere and to determine with accuracy the size, shape and position of the orbits of the satellites, and also to draw conclusions regarding the processes and occurrences taking place in the satellite during the course of its flight."

The second article mentions the use of two radio transmitters "having frequencies of approximately 20Mc/s and 40Mc/s, and the power of the transmissions will be approx. 1W. These transmitters will operate continuous over a long period (this period being limited by the sources of electrical power contained in the satellite). Consequently, the special radio reception points as well as radio amateurs throughout the whole of the territory of the Soviet Union as well as countries abroad will be able to receive time and time again the radio signals

Fig. 1. Elements of the orbit of an artificial satellite. (Reproduced, with acknowledgments, from Radio.)



* Going back as far as 1945 in this journal. See, for example, "Extra-Terrestrial Relays," by Arthur C. Clarke, October, 1945, issue.

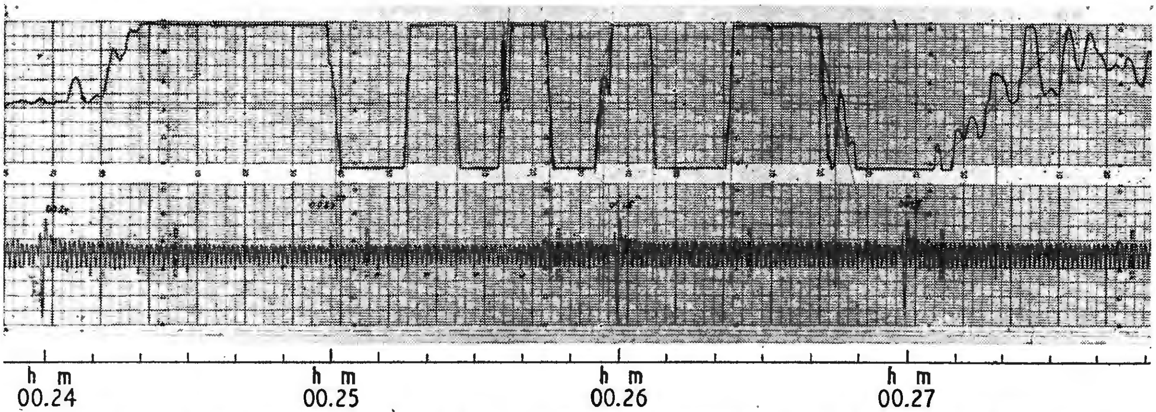


Fig. 2. Record of interferometer outbut taken from Sputnik I's 40-Mc/s transmission at Cambridge on October 6. The lower waveform is a timing reference, and the l-minute and 10-second intervals are shown on the scale below the chart.

transmitted by the equipment mounted in the satellites.

"The signals given out by the transmitters in the satellites will be similar to telegraphic strokes having a length of from 0.05 to 0.7 seconds. The transmission will be arranged to proceed in such a manner that one transmitter will be heard during the interval in the transmission of the other."

Of course, we know now that the actual pulse duration was approximately 0.3 second, on both frequencies in the first satellite and on 20Mc/s in the second satellite. Moreover the frequencies proved to be 20.005Mc/s and 40.002Mc/s—the increments of 0.005 and 0.002 being made probably in order to generate audio beat frequencies of 5kc/s and 2kc/s with local oscillations of 20Mc/s and 40Mc/s at the ground receiving stations. We know also that the 23-inch aluminium-alloy sphere of the first satellite carried four projecting rod aerials of 2.4-2.9 metres in length, which were folded back against its body during the flight in the rocket but afterwards swung out on swivels to their correct positions. The 184-lb weight of Sputnik I was said to have been largely made up by the weight of the batteries, which have been estimated as supplying a power of 10-30 watts.

The second satellite is reported by the Russians to contain a great deal more telemetering equipment —for measuring temperature and pressure, cosmic rays, electromagnetic radiation from the sun in the short-wave, ultra-violet and Röntgen regions, and also various physiological parameters from the passenger dog. Very little is known at present on the precise method of modulating all this information on to the radio frequencies, but it is likely that some time-sharing system is used, even though two carriers are available.

Pulse Recurrence Frequency

In Sputnik I, it was stated by the Russians that the mark/space ratio of the pulses was modulated and also "the frequency of the telegraphic messages". Whether this meant the radio frequency or the pulse recurrence frequency was not clear. The B.B.C. at Tatsfield noted a gradual increase in p.r.f. from 108 pulses per minute to 150 per minute before the keying on 20Mc/s stopped altogether on October 7. In the second satellite the keying on 20Mc/s stopped on November 3, leaving both transmissions in continuous operation.

Most people are by now familiar with the general nature of the orbits of the two satellites, but before passing on to the radio astronomy measurements it may be as well to look briefly at the basic astronomical parameters involved. For this purpose we quote from the June issue of *Radio* mentioned earlier.

Elements of the Orbit

"In consequence of the ellipticity of the orbit, the height of the satellite from the earth will vary during one revolution; the point at which the height of flight is maximum is called the *apogee*, whereas the point of minimum height is called the *perigee*. In order to be able to determine completely the shape, size and position of the orbit of such a satellite, it is sufficient to have a knowledge of five different magnitudes (Fig. 1): the height of the perigee, the height of the apogee, the inclination of the orbit (i.e. the angle which the plane of the orbit makes with the plane of the equator), the distance between the nodes (i.e., the angle which the line crossing the orbital plane and the equator makes with a given celestial line also lying in the plane of the equator—the line fixed by the vernal equinox) and, finally, the angular distance between the perigee and the node.

"These magnitudes are called the elements of the orbit; they provide the fundamental data required for determining the number of revolutions within a 24-hour period. They will have to be determined as many times as possible in order to ascertain the variations which will occur in the satellite's orbit† before it reaches the point at which it begins to fall rapidly and finally disintegrates.

". . . . The orbital plane of the satellite does not share in the rotation of the earth, whereas the observers, who are located on the surface of the earth, naturally follow the rotation of the earth from west to east. . . . During the time of one rotation of the artificial satellite (which will probably be approximately 1.5 hours) an observer located on the equator would be moved 2500 km towards the east,

† "As a result of the resistance of the atmosphere and also as a result of deviations of the pull of gravity from a central direction, the elements of the orbit will be gradually altered."

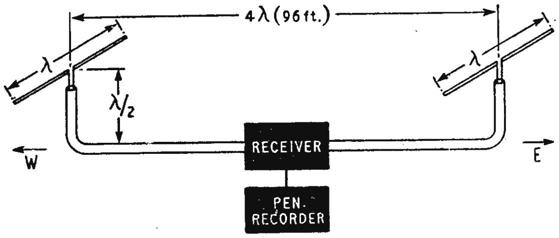


Fig. 3. Schematic of the 40-Mc/s interferometric aerial system at Cambridge. It was actually modified from a 38-Mc/s radio telescope used on radio stars.

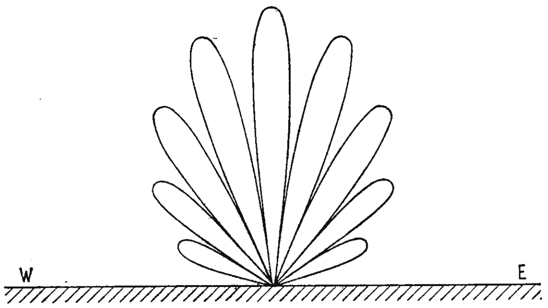


Fig. 4. General form of the interference-pattern type of polar diagram produced by the spaced aerial system in Fig. 3.

whereas an observer situated at a latitude of 45° would be moved 1760 km and an observer situated at a latitude of 60° would be moved 1000 km. The northern and southern limits of observation are determined by the inclination of the orbit of the satellite, which defines how far the satellite will move either to the north or to the south. During every period of twenty-four hours the artificial satellite will make 16 revolutions round the earth and in so doing will make, as it were, a regular pattern or 'network' over the earth's surface. The satellite to be launched in the U.S.S.R. will travel in such a manner that it will pass over practically every inhabited region of the earth.

"The time during which it will be possible at any given point on the earth's surface to pick up radio signals from the artificial satellite will be determined by the speed of the satellite (8 km per second) and the greatest distance at which it is possible to receive the signals transmitted. The time for receiving signals will probably last for several minutes."

The "several minutes" in the last paragraph is illustrated in practical terms in Fig. 2, which is one of the first recordings of Sputnik I's signals taken at the Mullard radio astronomy observatory at Cambridge. It was obtained at night in the first hour of October 6, and occupies a total time scale of nearly 5 minutes. This record is actually the output of a receiver fed from interferometric type of aerial system of the kind already described in *Wireless World*.‡ Two spaced dipoles are used, as shown in Fig. 3, giving an interference pattern consisting of multiple lobes as in the polar diagram Fig. 4. A source of signals like a satellite passing through this pattern therefore produces an output from the receiver which goes through maxima and minima of the kind shown on the record.

‡ "Radio Astronomy," July, 1951.

At any particular height above ground a plan view of the minima between lobes in Fig. 4 takes the form of a hyperbolic pattern, as shown in Fig. 5. The actual positions of these lines are established of course, from a knowledge of the geometry and geographical positioning of the aerial system (which is arranged on an accurately surveyed east-west line). Similar hyperbolic patterns can be drawn for all heights above ground. Thus, from the time intervals between minima on the Fig. 2 record and the roughly known velocity of the satellite (derived from the period of rotation), it is possible to calculate a series of points with particular spacings on a straight line that will fit on to one of the hyperbolic patterns. In this way the track of the satellite relative to the aerial system can be found, as shown in Fig. 5, while the hyperbolic pattern in use will give the height.

Measurements of this kind were made not only at Cambridge (on the 40Mc/s transmission) but also by the Royal Aircraft Establishment and the Royal Radar Establishment, both of whom used crossed interferometric aerial systems. All three establishments in addition took measurements of the changes in frequency produced by the Doppler effect. The results were used for calculating the velocity of the satellites and also for obtaining ranges from which the tracks could be obtained for correlation with the interferometric methods. To explain how the Doppler method is used to obtain this velocity and range information we again give a direct quotation from the *Radio* articles.

"The Doppler effect is concerned with the variations in frequency which are produced when the transmitter and receiver approach one another or move further apart from one another. The known principle is that when the source of the waves and the receiving station approach one another the frequency observed is higher than the emitted frequency. Conversely, if the transmitter and the receiver are receding from one another, the frequency as received will be lower than that emitted.

"The speed of approach or recession of the satellite will vary according to a special pattern on account of the elliptical shape of the satellite's orbit. It will readily be seen that it is not merely a ques-

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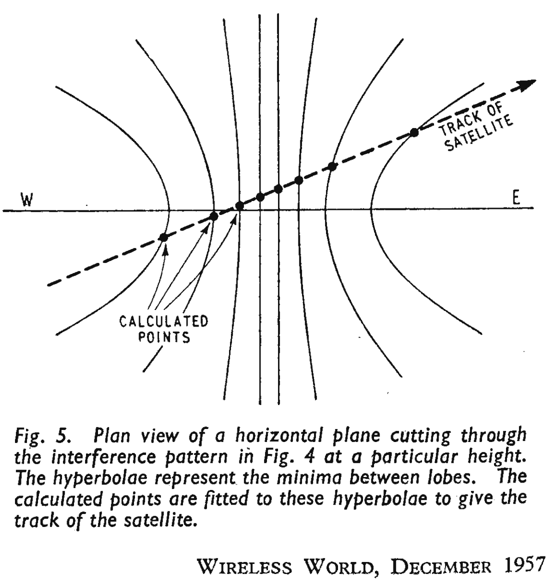


Fig. 5. Plan view of a horizontal plane cutting through the interference pattern in Fig. 4 at a particular height. The hyperbolae represent the minima between lobes. The calculated points are fitted to these hyperbolae to give the track of the satellite.

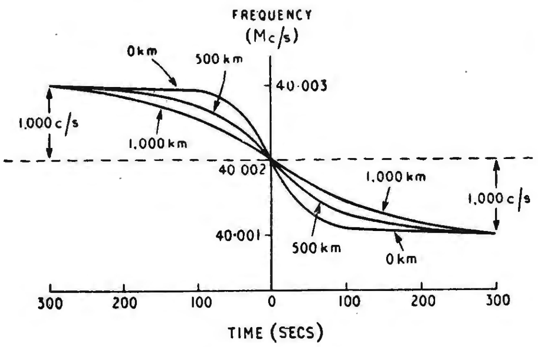


Fig. 6. Curves showing change of received frequency with time produced by the Doppler effect as a satellite approaches and recedes from the receiving station. The three curves represent transits at different ranges. The transmitted frequency is 40.002Mc/s. (Reproduced from Radio.)

tion of approaching in a straight line at constant velocity and then passing the observer station and receding at the same constant velocity. The speed in relation to the receiving station will vary according to the angle of the particular section of the orbit in relation to the point of observation. When the angle between the direction of movement of the satellite and the direction of the waves received by the receiving station is greater than 90°, the satellite commences to recede from the receiver; the velocity of this motion of recession gradually increases and reaches its maximum before the signals cease altogether. At first the signal will be found to have its maximum frequency, and then when the satellite gets near to the reception point the frequency will decrease somewhat, and finally, when the satellite is moving away from the observer, the frequency will decrease down to the minimum. This is shown in diagrammatical form in Fig. 6.

"The period during which the frequency change due to the Doppler effect will be noted will last for two to three minutes and consequently it is essential to be ready for measuring any differences before the satellite comes into range."

At Cambridge the frequency changes were measured by heterodyning the incoming satellite frequency of 40.002Mc/s with a local 40-Mc/s oscillator and comparing the resultant audio beat note with an equivalent signal from a calibrated variable a.f. oscillator. The comparison of audio frequencies was done by ear and by keeping a Lissajous figure stationary on a c.r. tube display. Readings were taken at 3-second intervals, to obtain graphs of the kind shown in the Russian diagram Fig. 6. As indicated, the total frequency change on 40.002Mc/s was about 2kc/s, taking place over periods of about 2 to 10 minutes or more, depending on the range. It will be noticed that the frequency transition occurs rapidly at short ranges and slowly at long ranges.

From the Doppler law relating the rate-of-change of the curve to the distance of the observer it is possible to calculate the actual range of the satellite on a particular transit. Measurements on two successive transits will then give the track and height by triangulation. At Cambridge the results of these Doppler observations were combined with those of the interferometric methods, and, as is well known, figures for the various parameters illustrated in Fig. 1 were obtained with extreme accuracy.** The inclination of the orbit was found to within ±10 minutes of arc, for example, the period of rotation to within ±0.3 seconds and the heights at the apogee and perigee to within ±10 kilometres. This was a remarkable achievement.

When the signals from Sputnik I ceased, greater attention was naturally focused on the radar observations. These were made at the Jodrell Bank radio astronomy establishment, using the giant 250-ft diameter radio telescope, and at the Royal Radar Establishment, Malvern, with a new 45-ft radio telescope.

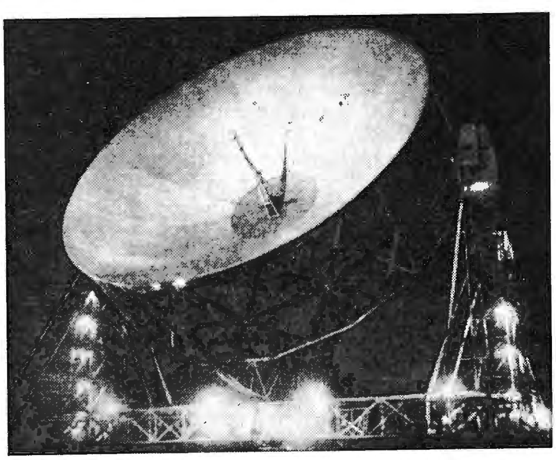
Ranges by Radar

Jodrell Bank operated with two radar transmitters. The first, on 36Mc/s, had a peak power of 10kW, a pulse duration of 150μsec and a p.r.f. of 75 per second. The second, working on 120Mc/s, also had a peak power of 10kW, with a pulse duration of 2msec and a p.r.f. of 10 or 20 per second. When observations were made on the orbiting rocket belonging to Sputnik I, the range of detection on 120Mc/s was limited only by earth curvature, and adequate signal/noise ratios were obtained at ranges of over 900 miles. The pencil beam of the 250-ft paraboloid has a calculated angular width of about 2°-3° at 120Mc/s and about 8° at 36Mc/s, while the calculated power gains at these frequencies are respectively 6,500 and 600. A much finer pencil beam was used at Malvern—only 0.5° in angular width—obtained with a frequency of 3,000Mc/s. Here, ranges of over 800 miles were reported on the rocket.

At the D.S.I.R. station at Slough and the B.B.C. station at Tatsfield, some interesting observations were made on the maximum ranges at which the satellite signals could be heard. With Sputnik I the signals were received for about 30-35 minutes on each satellite transit, which suggested that they were coming from far beyond the optical horizon (about 2,000 miles range) where one would not normally expect to hear them. In fact the range was about 4,000 miles. The probable explanation for this

** See for example "Radio Observations of the Russian Earth Satellite," *Nature*, November 2, 1957.

The 250ft steerable radio telescope used at Jodrell Bank Experimental Station for observing the satellites by radar techniques.



is, of course, that the waves from the satellite transmitter were refracted by the ionosphere (through which they would pass from outside) in such a way as to bend them round the curvature of the earth. The ionosphere was also no doubt responsible for the curious short burst of 20Mc/s which usually occurred before the main signal was received. At Slough most of the measurements were, in fact, done on 20Mc/s because of the greater effect of the ionosphere on that frequency. At Cambridge, on the other hand, they used mostly 40Mc/s in order to avoid the inaccuracies introduced by the ionosphere in the position-finding measurements.

Signal Strengths

Many different aerials were pressed into service by the B.B.C. at Tatsfield—open-wire types, horizontal rhombics, double rhombics, vertical "V"s, short-wave stacks—while receivers were standard communication types with beat frequency oscillators. Both signal-strength and frequency measurements (for Doppler calculations) were made. With the first satellite the signal strength was occasionally as high as 35μV/m during the first few days, but most of the time was only just above noise level. The signal from the Sputnik II was much weaker, as might be expected from the greater range, and was generally less reliable.

The variations recorded in the signal strength were, in fact, one of the most complex aspects of the satellite transmissions. There were several different periodicities in these fluctuations and a number of possible reasons for them. The report from Cambridge in *Nature*** mentions three likely effects: (a) rotation of the radiation patterns of the satellite's aerials by the spinning of the satellite; (b) changes of polarization in any plane-polarized component of the transmitted signal also produced by the spinning of the satellite; (c) changes of polarization caused by Faraday rotation†† in the ionosphere resulting from the earth's magnetic field. The June issue of the Russian journal *Radio,* incidentally, comments on the expected variations as follows:—

"... At some points in its movement the aerials of the satellite will be located in such a way that the wireless waves reaching the aerial of the receiving station will have a circular polarization. At other times the aerials fitted to the satellite will be pointing straight in the direction of the receiving aerials of the observer station, so that the waves reaching the receiving station have a linear polarization."

To distinguish between these possible effects the Cambridge observers fitted up receiving aerials with mutually perpendicular planes of polarization. It was then found that the fading patterns on the two aerials differed in phase by $\pi/2$, showing that the rotation of the plane of polarization was the most important cause of the signal fluctuations. To distinguish between the rotation due to spinning and that due to the Faraday effect, they made observations of the fading periodicities on both 20Mc/s and 40Mc/s. The significance here is that the Faraday rotation is proportional to the square of the wavelength, and, therefore, produces more rapid fading on 20Mc/s than on 40Mc/s. The fading due to the spinning of the satellite, however, is independent of frequency.

Curves have been plotted of several of the periodicities of fading against G.M.T. for both the 20-Mc/s and the 40-Mc/s signals. The two curves for a particular satellite transit coincide more or less exactly if the periodicity scale on 20Mc/s is arranged to represent values four times as big as those on the 40-Mc/s periodicity scale. In other words, at twice the wavelength the fading periodicity is quadrupled —which shows that the periodicity is proportional to the square of the wavelength and supports the hypothesis that some of the fading is, in fact, due to Faraday rotation.

The Cambridge observers also say in *Nature* that their fading periodicity measurements indicate that Sputnik I was spinning at seven revolutions per minute. It has been noticed that this spin fading is accompanied by a marked irregularity in the Doppler curves. The effect, they say, may be caused by the periodic reversal of the sense of the circularly polarized component of the transmission as the satellite spins.

The Faraday rotation measurements, among others, are likely to be of great value in the studies of the ionosphere which form part of the International Geophysical Year programme. As an example, the electron density of the ionosphere is of great interest. The angle of rotation of the plane of polarization of the transmitted wave is determined by the total number of electrons along the "line-of-sight" path to the receiving aerial. Consequently, as the satellite moves along its track the length of the path through the ionosphere changes and also the number of electrons. This in turn produces a change in the angle of rotation of the polarization, giving an alteration of signal strength at the ground receiving station. Knowing the track of the satellite and the inclination of the earth's magnetic field to the "line-of-sight" path, it is possible to find the rate of change of electron content along this path.

Ionospheric Refraction

The existence of radio transmitters above the ionosphere at varying heights and at varying angles of elevation make possible other types of investigations. To quote again from *Radio*: "It must also be borne in mind that the signals received from the artificial satellite will have had to pass right through the ionosphere and in so doing will doubtless be subjected to refraction, both on entering and on leaving the ionosphere. . . . In turn, the amount of this refraction will depend upon the wavelength, so that the data received from all sources regarding the reception conditions of both signals on their different wavelengths will, when properly collated, supply further information regarding the structure of the higher strata of the earth's atmosphere."

As an example of this, the Cambridge workers mention in *Nature* measurements which allow the angle of refraction of the waves to be found at different angles of elevation. The angles of arrival of the 20-Mc/s and 40-Mc/s signals are measured by comparing the apparent times at which the source crosses the minima lines of similar interferometers working on these respective frequencies.

Preliminary measurements of this kind have already been done at Cambridge. They mark the beginning of a new era of scientific study, which has only been made possible by the tremendous technical achievement of planting these radio stations in space beyond the ionosphere.

†† A brief explanation of Faraday rotation was given in the December, 1956, issue, p. 595.

Satellite Observations for Amateurs

By O. J. RUSSELL,* B.Sc. (Hons.), A.Inst.P.

THE use of frequencies of 20 to 40 Mc/s in the Russian satellites opened up the possibility of large-scale amateur observations with gear already to hand in most amateur stations. It is hoped that some American satellites will also employ such frequencies in view of the larger numbers of amateurs who may participate. The original announcement that the American satellite project would use minimum power transmitters, requiring specialized aerial systems and very low noise-factor 108-Mc/s receivers, and would use equatorial orbits that would prevent any reasonable possibility of reception in these latitudes, had discouraged British satellite observing programmes. The Russian launchings have altered this situation drastically, and lead to the hope that American satellite projects will also enable observers to participate with easily obtainable equipment.

Receiving equipment for 20 Mc/s may be almost any type of conventional communication receiver. If well warmed up, such receivers will be stable enough for the Doppler shift measurements of velocity. A better solution is the use of a crystal-controlled converter (see Fig. 1), enabling the communication receiver to be used on a low frequency band—say 3 Mc/s, where stability will be enhanced, thus facilitating Doppler measurements. For 40 Mc/s a similar converter is ideal, and had information on frequencies been generally known, many such equipments would have been in use. However, most amateurs were able to utilize the 20-Mc/s channel straight away. For possible 108-Mc/s observations, a low noise crystal-controlled converter of the type used for 2-metre reception would be suitable. Such converters may be adapted from existing 2-metre converters.

Aerial systems may have any degree of complexity. A simple vertical aerial is ideal for Doppler and general long-range observation of the satellite signals. The all-round low-angle polar diagram of a vertical aerial is very suited to this work. The vertical may consist of a 12-ft vertical rod or wire, coaxially fed, and may be elaborated into ground-plane and similar aerial types. Tracking the satellites by the use of a rotating beam array is unlikely to be very accurate or satisfactory by "peaking" for maximum signal strength. However, by tracking on the minimum signal in an "end on" null, even a simple rotary dipole may be satisfactory. With conventional 21-Mc/s beams, it will often be found that the beam "works backwards," owing to the reflector becoming in effect a director on the lower frequency.

A simple minimum radio interferometer is shown in Fig. 2. For a vertical transit of the satellite, this will give three null positions, and ideally these are sufficient, if the velocity is known from Doppler measurements, to fix uniquely the height and track of a satellite. For other than a vertical overhead transit, the central null will lie on a straight line but the other nulls will lie on hyperbolæ, as already shown in the previous article. If space is available greater separation of the dipoles of the interferometer may be used, so that more nulls may be obtained and the track fixed more certainly.

For the practical arrangement, triply folded wire

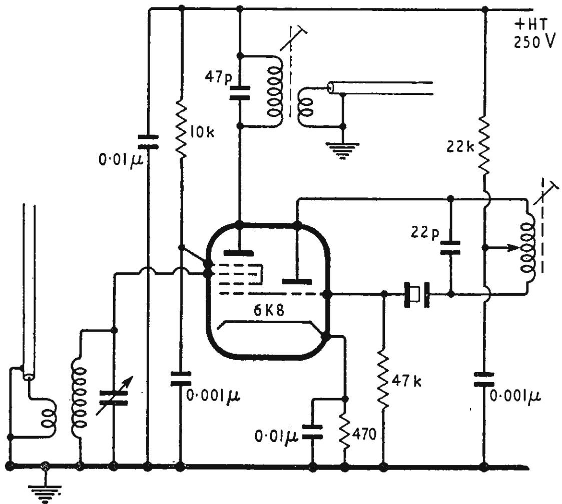


Fig. 1. A simple crystal-controlled mixer stage may be used as a frequency converter. A Squier type of overtone oscillator using the third harmonic will function with ordinary production crystals. For a 4-Mc/s i.f. a crystal with a 5.333-Mc/s fundamental will serve for 20-Mc/s reception, and a 12-Mc/s crystal will serve for 40 Mc/s. For optimum results an r.f. stage should be used in front of the mixer stage.

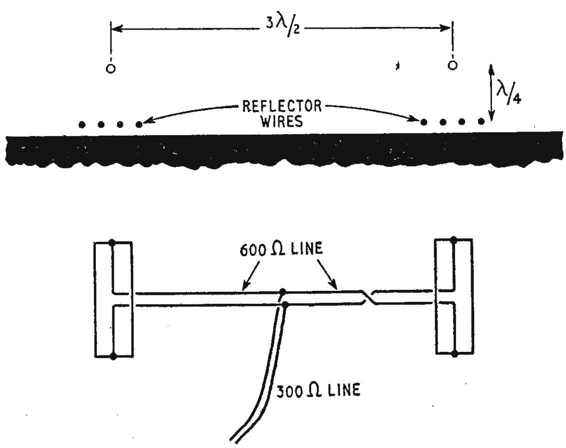


Fig. 2. Schematic of a simple interferometer aerial system giving three null points. At the altitude of the satellites the two outside nulls lie on hyperbolæ as shown in Fig. 5 of the previous article on page 576.

*Amateur station G3BHJ.

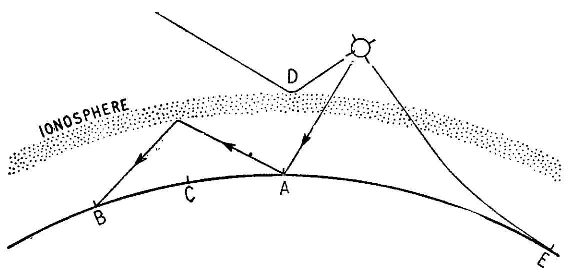


Fig. 3. Some possibilities in reception of satellite signals. At A the direct wave is received. B receives a ground and ionospherically reflected signal, while C is in a skip zone receiving no signals, as the direct ray is reflected into space at D by the ionosphere. At E atmospheric refraction extends the ground wave.

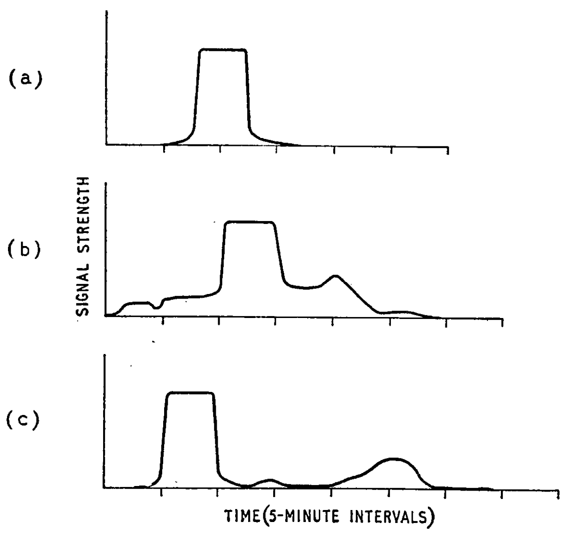


Fig. 4. Signals as received under varying ionospheric conditions. At (a) the signal is as heard with negligible ionospheric effects. At (b) some ionospheric reflection prolongs audibility. At (c) the satellite traverses a skip zone, and again peaks into good audibility after the true transit.

dipoles will match nicely into 600-Ω spaced feeder line. The feeder line should be air-spaced, using light-weight spreaders. Wax impregnated dowel rods are light and quite suitable, being somewhat more convenient than heavy ceramic spacers. The physical centre between the two dipoles is used as the point to attach a 300-Ω line to the receiver. By using the $1\frac{1}{2}\lambda$ spacing and transposing one 600-Ω feed line as shown, the simplest possible interferometer giving a central null and two other nulls, one each side of it, is achieved in a reasonably small space. Two amateurs, both using such systems in directions at right angles to each other, will be able to obtain valuable data for track estimation, on the principles already described in the previous article.

For the 20-Mc/s frequency one wavelength may be taken as 49ft. The folded dipoles should be cut to a length 5% less than this, but being inherently broad-band a round length of 47ft will be satisfactory. They should be supported a quarter wavelength above four reflector wires which are half a wavelength long and separated by 2ft from each other. The reflector wires need only be a few inches above ground level. For 40 Mc/s these dimensions may be halved. On this higher frequency the erection of interferometers of greater spacing will be facilitated, so that more nulls may be achieved and more "zero signal" observations made to obtain more useful data.

Signal observations may be made with any degree of elaborateness, ranging from simple "listening to the signal" upwards—depending on what equipment is available. At a close transit the optical-path condition for the first satellite was some 1,500-2,000 miles in either direction, so that the transmitters were audible in direct line-of-sight for a path length of about 3,000-4,000 miles. For less close approaches optical path conditions will be shorter. Under these conditions, representing little or no ionospheric transmission and the inaudibility of the WWV transmission, the signal suddenly leaps into audibility, peaks to a very strong value, maintained almost rock steady, and then rapidly declines to a weak signal. Having thus heard the signal appear on a dead band after hours spent listening to receiver noise was an eerie and exciting experience. Generally, once the signal has appeared, a weak signal is audible for some three or four minutes after it is beyond the optical horizon, under conditions of little or no ionospheric propagation. Under "good DX" conditions, with a high level of ionospheric ionization, the signal may undergo a number of vicissitudes, as shown in Fig. 3. Under such conditions the satellite signals may be heard well in advance of transit time, and long after. Some amateurs have followed the signals for upwards of an hour. Moreover the writer has heard the signal disappear, traverse a skip zone and again peak into audibility. Cross-observations on the strengths of the 20- and 40-Mc/s transmissions may thus yield valuable information about ionospheric conditions, as mentioned in the previous article.

For Doppler shift measurements a close transit is not necessary, for at 1,500 miles range the approach is practically head-on initially, and corrections that are quite small may be made if necessary. Moreover, in these latitudes even the correction for the rotational velocity of the earth is small, and will never exceed some 500 miles per hour. Aural estimates made by setting the receiver b.f.o. to zero beat and measuring the change in b.f.o. setting over a transit are unlikely to be better than within some 30-50 c/s. Moreover the sweep of the conventional b.f.o. is too wide to enable accurate calibration to be made. A very small variable capacitor of one or two picofarads connected from the b.f.o. valve grid to earth will give a vernier control which may be calibrated in cycles to enable accurate measurements to be made. A cathode ray tube comparison system using Lissajous figures, as mentioned in the previous article, will enable measurements to be made to less than a cycle. The "conversion factor" is almost precisely 1.5 cycles per megacycle of received frequency per thousand miles per hour. A more accurate figure is 1.491 cycles. Thus, on 20 Mc/s for a satellite velocity of 18,000 miles per hour, we should observe the frequency 540 c/s high when approaching end on, and 540 c/s low when receding end on.

Finally, the unexpected must always be expected in such observations. Undue reliance need not be placed upon newspaper reports. The transmissions from WWV on 20 Mc/s precisely provide exact timing signals—and they also provide tone plus pulse transmissions which have deluded official and other observers unacquainted with such matters that they were hearing the "bleeps" of the first satellite. The 1-Mc/s harmonic marker frequencies from a Class D wavemeter are also useful for locating the frequency, particularly as disturbed conditions have prevented WWV signals from being heard on many occasions. Estimates of " tone " quality should also be made, as variations in this may well be due to frequency modulation telemetering. This, of course, is standard procedure, which has appeared in the popular newspapers as " mystery code signals baffle observers ". The only mystery, however, has been the calibration scale and what particular variable was being measured.

Simple Measurement of Phase Difference

By Squadron Leader G. de VISME, B.Sc.

DIRECT INDICATION OF SIN θ BY VALVE VOLTMETER

AMONG the number of methods which exist for measuring the phase difference between two sinusoids of the same frequency are the following:—

(1) Lissajous ellipses derived from the sinusoids are displayed on a cathode ray oscilloscope, and in terms of the ratio of vertical to horizontal extent thereof, the phase difference can be calculated. The amplitudes of the sinusoids have first to be equalized. The determination of which is the leading sinusoid presents a further problem.

(2) The phase of one sinusoid is advanced or retarded as necessary to bring it into phase, or anti-phase, with the other; the control for doing this may be calibrated directly in degrees.

(3) The sinusoids are separately squared, the resulting square waves added, and the final waveform rectified. The d.c. level of the rectified sum depends on the phase difference of the sinusoids, being zero for 180 degrees phase difference and a maximum for zero phase difference. The square wave amplitudes have to be equal to start with. Again, ambiguity exists as to which wave leads which.

(4) A modification of (3) exists whereby the square waves are differentiated, the resulting pulse trains being used respectively to switch each valve of an Eccles-Jordan relay. The mean anode current of one or other of the valves is proportional to the angle of phase difference. Once again there is ambiguity as to which sinusoid leads which.

(5) One sinusoid is fed into a phase splitter, the two outputs of which (whose amplitudes must be equalized) are fed one to each of the anodes of two diodes connected as a balanced modulator. The other sinusoid is fed equally to each anode. The net output across the two diode loads in series is a (rather complex) function of the phase difference.

The above methods all suffer from one or more defects—either they are complicated, or frequency-sensitive, or the output bears a complex relation to the phase difference, or there is ambiguity as to which is the leading wave.

Basic Theory

The method to be outlined has the advantage of extreme simplicity and is, in theory at least, almost independent of frequency. The ambiguity as regards lead or lag still occurs, but a comparatively simple addition is suggested which avoids this. Using a phase-shifting device consisting of accurately measured components so as to give an

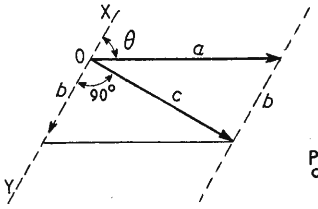
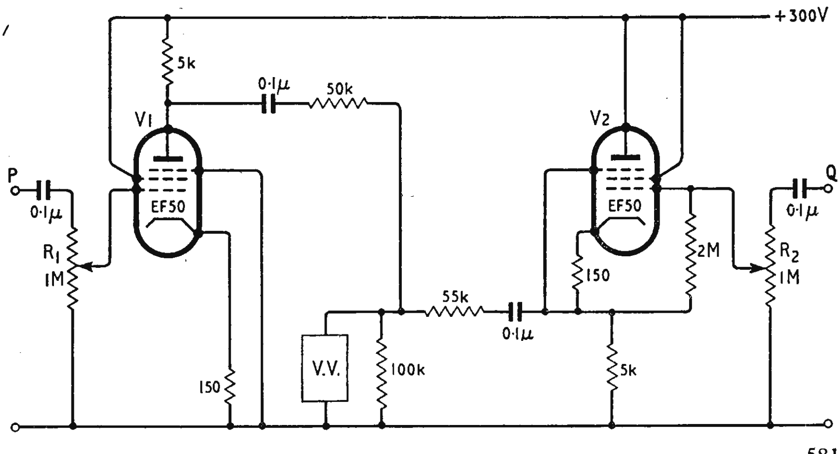


Fig. 1. Vector diagram of measurement procedure.



Right: Fig. 2. Circuit for the measurement of phase-difference.

accurately known phase shift, the measured phase difference tallied with the calculated value to within less than 1% in the range 100 to 2,000 c/s.

Suppose the two sinusoids differ in phase by less than 90 degrees; then, if one is reversed in phase and added to the other, its amplitude may be adjusted to make the amplitude of the resultant a minimum. If the un-reversed signal is initially adjusted to yield a deflection of 1 on a valve voltmeter, the minimum resultant will give a deflection of sin θ, where θ is the phase difference.

Thus, in Fig. 1, let a be the generating vector of one of the sinusoids, and let OX be the direction of the generating vector of the other, so that OX makes an angle θ with a. The vector along OX will, after phase reversal, lie along OY. Its length has to be adjusted so that its vector sum with a has least length; let it be b when so adjusted. For the resultant c to be of minimum length it must lie at right angles to XY, this giving the shortest path between the two parallel lines shown dotted in Fig. 1. Thus in the right-angled triangle so formed $c/a = \sin\theta$. Evidently, had the direction OX lagged a by θ, exactly the same condition would have obtained—hence the ambiguity.

A Practical Circuit

The required circuit is shown in Fig. 2. It is seen that the addition takes place in the common resistance (100 kΩ). V1 is the phase reversing valve, while V2 is a cathode follower, with a very large input and a very small output impedance. Two points have to be observed in connection with the circuit. In the first place, the phase shifts introduced by the respective input networks, whilst necessarily not zero, must at least be equal. Secondly, for accurate addition, the total impedances of the series arms of the adding network must be equal in both magnitude and phase—hence the resistance values.

The operation is as follows:—

(i) Connect the sinusoid sources respectively to points P and Q.

(ii) Turn the potentiometer R_1 to zero and adjust potentiometer R_2 so that the reading on the valve-voltmeter is 1, or if possible 10, volts.

(iii) Adjust R_1 till the reading on the valve-voltmeter is at a minimum. This reading is sin θ or 10sin θ, according to the original reading on the meter.

To decide whether θ is a lead or a lag, a small phase lag is introduced into the input to P by the circuit shown in Fig. 3, and the control R_1 is adjusted to give a new minimum. If the new minimum exceeds the original, the input to P lags the input to Q, and vice versa.

If θ is large, say 85°, it is possible that no new minimum will be attainable after introducing the lag—even with R_1 set at zero. This implies that the input to P lags that to Q by 85°. Had the reverse been the case, introducing the lag would have caused a drop in the minimum.

For θ very small, say 2°, it is very hard to decide for certain whether it is a lead or a lag by comparing the minima before and after the added phase lag, since the minimum is so small anyway. The phase-lagging device can be set to give only a very small lag indeed—comparable with 2° in fact—and its effect on the value of the minimum is then just detectable.

In Fig. 3, V3 is a cathode follower, while V4 is a Miller valve presenting an input capacity equal to (1+A) times the anode-grid capacity, i.e. (1+A) ×(300 pF). The series potentiometer (100 kΩ) and the 100 kΩ potentiometer in the anode circuit of the Miller valve are ganged, and are both logarithmic. The RC circuit producing the phase lag therefore has its R and C simultaneously variable. The resistance of either potentiometer can be accurately controlled from about 1 kΩ to 100 kΩ, and so a given phase lag, say 10°, can be derived at any frequency from 10 c/s, say, to $10^4 \times 10$ c/s = 100 kc/s, with one sweep of the dial. This dial is accordingly calibrated logarithmically in frequency from 10 c/s to 100 kc/s, so that at a given setting, say 1 kc/s, the device produces a phase lag of 10° at 1 kc/s. If a smaller phase lag is required, it is only necessary to turn the dial to a higher frequency setting, and vice versa. The 680-Ω resistance in the Miller valve cathode enables this valve to handle the greatest possible input without distortion, consistent with admitting a 100 to 1 gain change.

It can be seen from the vector diagram of Fig. 1 that for phase differences of more than 90° this method does not give a true minimum, and the smallest obtainable vector sum corresponds to sin θ =1 and no input from R_1. In this case neither sinusoid should be reversed in phase. By simply adding to the circuit of Fig. 2 a potentiometer connected between the anode and un-bypassed cathode of V1, and deriving the signal from the sliding contact, we can obtain this sinusoid reversed or unreversed, as necessary.

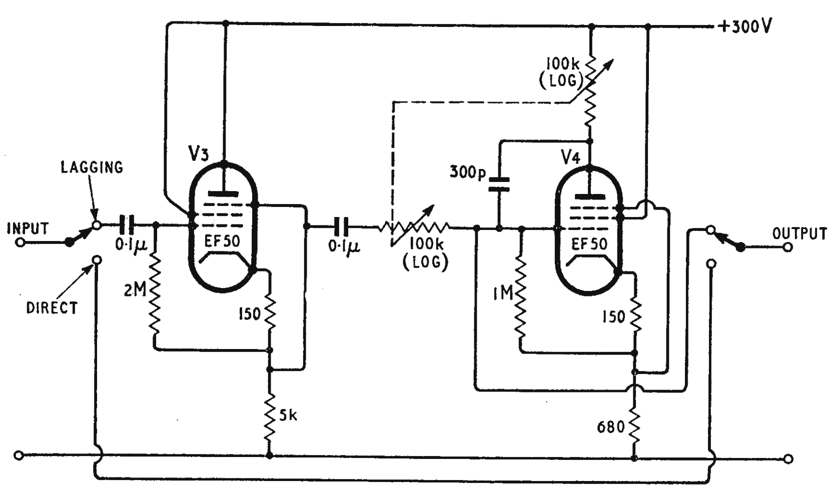


Fig. 3. Additional circuit to secure a small known phase lag.

RETURN LOSS

By THOMAS RODDAM

2.—Return Loss and the Television Picture

LAST month I discussed the convenience of the return loss concept in carrying out calculations on mismatched lines. At each junction, you will remember, we can determine this quantity—we shall come to details of methods later—and then, by imagining a very short impulse sent down the line, we can work out the sort of pulse train which will arrive at the point of observation. We have seen in a practical case, too, how such delayed echoes can distort the signal. In place of the standing wave ratio, which tells us how the signal is distorted in space, the return loss offers a direct approach to the problem of determining how the signal is distorted in time. Since we are rarely in several places at once, but often in one place for some time (especially when time is measured in the milli- and microseconds of the radio engineer), the return-loss method appears to be the most suitable one to use.

The purpose of all this is, of course, to find out whether the circuit is a satisfactory one, whether it needs changes to improve the matching somewhere, or perhaps even if we could relax our tolerances on some parts of the system and save a little money. We must, therefore, be prepared to set some sort of limits to the distortion which a practical signal can be allowed to suffer in transmission.

Return Loss and Response Curves

Usually in setting limits for a transmission system we make use of the steady state characteristics, i.e. the amplitude and phase responses plotted as functions of frequency. Sometimes you will find references to wavy amplitude responses as standing wave responses, because if a system has a wavy response in space at one frequency it will usually, but not always, have a wavy response in frequency at one point; but this sort of muddled thinking can lead to serious difficulties. Since we want to be able to find the frequency response, and since we also want to work with return loss, it is worthwhile tying the two together by a small amount of mathematics.

The easiest way of tackling the problem seems to be to consider a steady single-frequency signal which can be represented as $\exp j\omega t$. Exp x is another way of writing ϵ^x with the advantages that it is all on one line, allows larger print to be used for x, and that it takes one's mind away from the "raising to the power" angle, and reminds one of the functional nature of exp. We have, of course, the basic equation $\exp jx = \cos x + j \sin x$, so that we can always get back to cosines by taking the real part and throwing away the rest.

Travelling down the line then, we have a unit signal $\exp j\omega t$: we need not write $A \exp j\omega t$ because A can be unity if we choose. We choose. We also have a reflected wave travelling back from the mismatch at the termination. There may be several reflected waves sent back from various junctions, but let us stick to one for the moment. This reflected wave has an amplitude m; and is delayed by a time τ, since it has travelled down the line and back again. It can, therefore be written $m \exp j\omega\,(t-\tau)$. The total signal is then the sum of those two, that is $\exp j\omega t + m \exp j\omega\,(t - \tau)$. But we know that $\exp (a - b) = \exp a \,.\, \exp (- b)$, so that the total signal equals $\exp j\omega t\,[1 + m \exp (- j\omega\tau)]$.

This means that the original $\exp j\omega t$ has been modulated by an amount $m \exp (- j\omega\tau)$. For small values of m this reduces to an amplitude modulation term $(1 + m \cos j\omega\tau)$, and a phase modulation of arc tan $(m \sin \omega\tau/[1 + m \cos \omega\tau]) \simeq m \sin \omega\tau$.

There are some rather important relations to be derived here. The maximum and minimum amplitudes are, of course, $(1 + m)$ and $(1 - m)$. Now we know that m (a number) is directly related to the return loss (a decibel quantity), and that

$$m = \frac{Z_0 - Z_1}{Z_0 + Z_1}$$

provided that we measure the return loss at the point under consideration to get the apparent Z_1. Consequently,

$$(1 - m^2) = \frac{4Z_0Z_1}{(Z_0 + Z_1)^2}$$

But $10 \log (Z_0 + Z_1)^2/4Z_0Z_1$ is the *reflection* loss, which is therefore also equal to $- 10 \log (1 - m^2)$. A quick look in the textbooks (Hardy, "A Course on Pure Mathematics", 10th edn., p. 400, Cambridge University Press) shows us that

$10m^2 < - 10 \log (1 - m^2) \leqslant 10\, m^2/(1 - m^2)$ for $0 < m^2 < 1$.

This enables us to get a pretty good idea of the reflection loss in terms of the size of the ripples in the amplitude response. For example, if the response showed 1 dB ripples we should have $m \simeq 0.1$ so that the reflection loss $- 10 \log (1 - m^2)$ would be very close to $10\, m^2$ or 0.1 dB. The ripples in the phase characteristic have an amplitude of m radians, in this case about 6°.

Echoes and Response Curves

I am not going to do any more mathematics here, although the case of two echoes is both interesting and important. You can find it mentioned in the appendix to a paper by Mertz (*J. Soc. M.P.T.E.* Vol. 60 p. 572, 1953). Especially interesting is the possibility of a pre-echo, if we may call it that, which enables us to get a flat phase characteristic but ripples in the amplitude characteristic or, to a first approximation, a flat amplitude with ripples in the phase characteristic.

Before going any further there is one important simplification to be made. Most systems we consider are of finite size, so that the signal takes a finite time to get from input to output. This delay time corresponds to a phase characteristic which is a straight line when plotted against frequency, the slope

$d\phi/d\omega$ being equal to the delay. We shall not cause any error in our studies if we put our clocks back and make this delay time zero. The phase shift should then also be zero, and we can concentrate on the deviations from the horizontal straight line, the zero phase axis. The results of our mathematics have been summarized by Mertz (loc. cit.) who refers us back to Wheeler (*Proc. I.R.E.* Vol. 27, p. 359, 1939). Mertz says:

1. A single echo appears as an array of ripples or sinusoidal scallops in both the amplitude response and phase characteristics.

2. The delay of the echo from the main signal influences the coarseness or fineness of structure of the scallops. The echo delay is inversely proportional to the wavelengths of the scallops measured along the frequency scale in the plotted characteristics.

3. The amplitude of the echo, relative to that of the main signal, influences the amplitude of excursion of the scallops. The relative echo amplitude (if small enough) is equal to the peak-to-zero excursion in the amplitude response characteristic, measured in nepers. It is equal similarly to the phase shift peak-to-zero excursion, measured in radians.

4. There is a phase shift of 90° between the array of ripples in the amplitude response characteristic and that in the phase characteristic. That is, the former are cosinusoidal, and the latter sinusoidal, ripples.

In Fig. 1 you can see how the echo spacing is related to the amplitude and phase responses. The particular features to be noted are the relationship between echo spacing and ripple frequency (the closer the echo the fewer the ripples in amplitude and phase response in a given band-width); and the sideways shift of the phase ripples with respect to the amplitude ripples.

Very often in the literature you will find references made, not to the phase characteristic, but to the delay characteristic. There are actually two different delay characteristics, and it is not too difficult to get confused between them. I wouldn't be at all surprised if " Cathode Ray " has already dealt with this question: if not, he probably will. But until that happy day let us take a quick look at Fig. 2, which represents a quite arbitrary phase characteristic. A nice smooth curve, drawn the way it is just to remind you of a triode anode-current/anode-voltage characteristic.

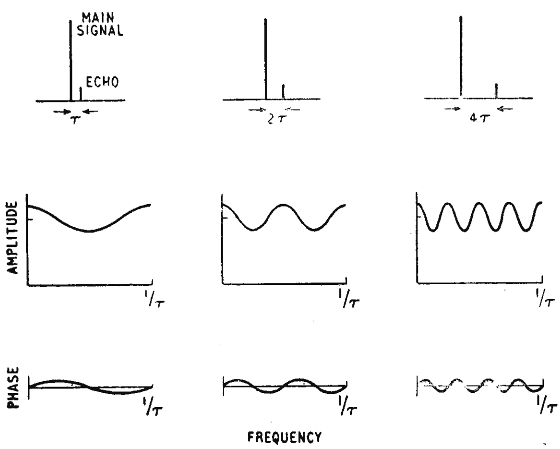


Fig. 1. Amplitude and phase response characteristics associated with various single-echo spacings.

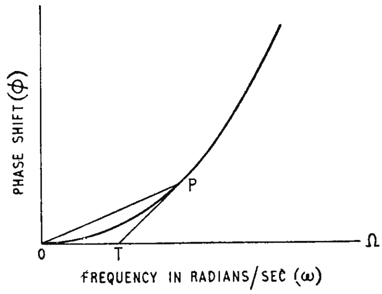


Fig. 2. Triode-like phase characteristic.

At the point P, the phase shift is ϕ and the frequency (the radians/second) ω. The slope of the line OP is $\tan^{-1}$POΩ and is, of course, ϕ/ω. The slope of the actual phase characteristics at P is the slope of the tangent line PT, and is $\tan^{-1}$PTΩ. This, of course, is $d\phi/d\omega$. The first of these, ϕ/ω, is called the phase delay, while the second, $d\phi/d\omega$, is called the envelope delay. It may seem odd to you, if you haven't met this before, that there should be two kinds of delay. That is why I drew a triode-like sort of curve. We are all quite happy to say " This valve takes 5 mA at 200 volts; and has an impedance of 10,000 ohms." Applying Ohm's Law, however, the impedance would seem to be $200/(5 \times 10^{-3})$, or 40,000 ohms. Most of us never consciously consider that the valve has two equivalent impedances, one for the steady h.t. supply (40,000 ohms), and one for small signals (10,000 ohms), the 10,000 ohms being, as you well know, the incremental impedance.

Envelope delay gets its name from the analytic process of considering what happens when two steady signals at frequencies ω and $\omega + d\omega$ are applied to a circuit. These beat together, and the delay experienced by the quasi-signal, the beat peak, is found to be $d\phi/d\omega$. If $d\phi/d\omega$ is constant over the band needed to transmit a pulse, $d\phi/d\omega$ is the actual pulse delay: if $d\phi/d\omega$ is not constant, there is some dispersion and the pulse loses its shape. You cannot measure exactly the velocity of a pig through a sausage factory.

We are, at the moment, considering a single clear echo. How big can it be before we object to it? The clearest collection of data is that given by Mertz (loc. cit.) whose Fig. 7 is reproduced as Fig. 3. Mertz gives some notes on these curves, which are best quoted in full:

(a) Mertz. A suggestion, based largely on experience with picture transmission, on the course to be expected of the tolerance as a function of echo delay.

(b) Doba (1949, unpublished memorandum). Relative values of tolerance indicated, adjusted toward crosstalk limit at long delays. Picture consisted of small solid rectangles on a flat field.

(c) Mertz, Fowler and Christopher. Data on only two delays, summarized for two pictures. Figures are for echo " just perceptible " to median observers, and " impairment to picture, but not objectionable," or worse, to most critical 10% of observers.

(d) Christopher (1950, unpublished memorandum). Data covering pictures and engraved geometrical figures. Form of summary curve, taken as reasonably representative, smoothed from data.

(e) Fowler and Christopher. Echo " just perceptible " to median observer. Single sensitive picture.

(*Continued on page 585*)

(f) International Radio Consultative Committee. Limits recommended for overshoot and echoes. These are really for a 405-line 3-Mc/s video band system.

In considering these curves we should not, I think, lay too much stress on (a), which represents figures put up just after the war as " probable good practice." This curve is really a guide to the experiments which led to the setting up of the standards of curve (f). Now C.C.I. standards tend to be better than domestic standards. Norman Douglas, I think it was, said somewhere that you should never give a man a dinner more than 10% better than he would get at home. The C.C.I. view seems to be to replace never by always: even engineers want to know that they are keeping up with the Jones'. The smooth curve (d), given by Christopher, looks like a reasonable target for the designer, with about 6 dB to spare before anyone is likely to be at all worried.

The echo delay in Fig. 3 is given in microseconds. For transmission along cables the velocity of the signal will be about 2×10^{10} cm/sec., or 200 metres/microsecond. This means that, if the signal travels 100 metres to a mismatch and then travels back to the observer, the echo pulse will have gone 200 metres and will be delayed by 1 microsecond. We could therefore add to the bottom of Fig. 3 a second scale saying " distance to reflector in hundreds of metres," with the same number positions. This then gives us all the information we need for studying a television transmission network—which could just be the aerial you share with your neighbour.

Distortion Due to Echoes

It is, to my mind, much easier to understand the way in which the picture is distorted due to each picture element having a small echo, than to try to make an estimate of the subjective effect of a non-uniform phase characteristic. There used to be some gramophone records, made I think by the German Siemens Company, of speech which had been transmitted over a very long telephone line without phase equalization. You could hear quite distinctly the difference in time of arrival between the high-pitched " sh " sound and the deep " uh." In the same way you can proceed from the idea of an echo to the phase curves of Fig. 1. You can then in terms of Fig. 3 find the corresponding criteria for either the shape of the phase curve, or the shape of one of the delay curves. It is then quite reasonable to say that any device which has such and such sort of phase or delay curve will produce a given echo. We have already seen, indeed, that the size of the echo is equal to the amplitude of the phase shift wave (half the peak-to-peak) measured in radians. We have also seen that if the " modulation frequency " of the phase characteristic is $1/\tau$, then the echo delay is just τ. This theme can be expanded in detail, and it offers a very simple method of turning an amplifier phase characteristic into picture distortion. Inside the black box which is our amplifier we have something which behaves to some extent like an echo chamber.

More important at this stage is the effect of distorting the echo. If the echo is differentiated, two small pulses, one of which is inverted, are produced from the original pulse, and, according to experimental evidence, differentiated echoes may be about 10-15 dB larger than the full echo. Here again we can construct the appropriate phase, phase delay, and envelope delay curves and apply tolerances to them. From the various ways of plotting the phase curve corresponding to a differentiated echo you can again work back to interpret a black box phase response as a differentiated echo, if this is appropriate, and thus treat a wider range of black box responses in terms of their echo form. To do this in any detail would need an article to itself.

A point of very great importance is the fact that when the echo delay time is zero the echo amplitude is not important, except, of course, that the reflection loss must be considered. This means that a device which produces, as some people will put it, standing waves does not itself suffer. It is only when the echo gets back along the line that it can do any real harm.

The reader will, I hope, already have realized that the right-hand part of Fig. 3 applies to the ordinary ghost of television reception. It is one

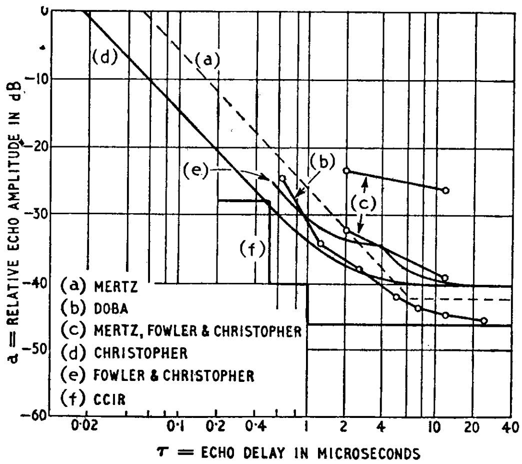


Fig. 3. Reported tolerances on echo amplitude as a function of echo delay.

of the advantages of this pulse and echo method of analysing the behaviour of circuits that it ties together as a single story a whole set of phenomena which would otherwise be treated piecemeal. What is more, the single story is one which is directly related to the final subjective effect. This idea of asking what happens to a pulse is one which has wide applications. It can be used, for example, in estimating the transient response of a feedback amplifier, where the first signal to arrive at the output has been amplified by the full gain of the amplifier in many cases. This initial spike is followed by the main body of the pulse in which the signal has had time to travel round the feedback loop and through the amplifier a second time.

Audio frequency applications of return loss are not so important to readers of *Wireless World.* The echo treatment shows that you must have plenty of room for the echo to get separated from the main signal. In television a microsecond is quite a long time, but in ordinary audio work we don't have to worry about much less than 100 microseconds, and that means that we need 10,000 metres to get our pulse and echo separated enough. This is not, however, very far for a trunk telephone network, so that the telephone transmission man is always aware of return loss. It is just within the range of interest for the wire broadcasting people. At power frequencies, where a pulse of about 10 microseconds would be the one to consider, the line length would need to be about 600 miles. This is a practical length of course for long trunk lines, and at points where the echo and the signal (the supply) reinforce each other (i.e. when τ is an integral multiple of 1/50 sec) the voltage on the line can go well above its normal value if the load comes off. I cannot remember if anyone has gone above 400 kV yet, but you will see that a 25% echo, adding another 100 kV, would be a pretty alarming thing to happen to anybody's power line.

Return Loss Measurement

It still remains to discuss the way in which we can measure the return loss which our apparatus gives when we use it at the end of a line. Measurement consists of the comparison of an unknown quantity, the quantity to be measured, with a known standard. This is, of course, a truism, though if you look at the "Philosophy of Physical Science" by Sir Arthur Eddington (Cambridge University Press, 1939), you will find that two thirds of the text are devoted to paving the way for general statements

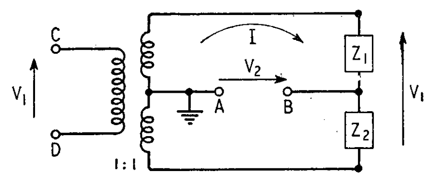


Fig. 4. Basic bridge circuit used in return loss measurement.

on measurement and observation. Usually, of course, the standard with which we make the comparison is, directly or indirectly, a fundamental standard. We could, I have no doubt, trace the sub^{n}-standard pint back to the standard kilogram. Return loss is not defined to be measured in this way against the background of the basic units. The question we ask when measuring return loss is not really "How many units of such and such?", but rather, "How nearly does this resemble that?".

Immediately after writing the last phrase it became apparent that it must be qualified. We may, in measuring return loss, ask either of two questions. "How far does this deviate from that?" is the first question, to which we may add "and in what manner?" as the second. In general, we find that we are only interested in the first question when we are concerned with what are so elegantly termed "user aspects." For buying or selling, or installing a piece of equipment, we may wish to know that the return loss against the nominal or actual line impedance is greater than x dB, and our interest will end there. When we are designing or adjusting a piece of apparatus, on the other hand, we wish to know how the impedance deviates from the ideal in order that we may attempt to correct it. We have distinguished between these two reasons for measurement because rather different experimental methods are used.

Let us consider the circuit shown in Fig. 4. This form of bridge circuit, using a centre-tapped transformer, is well known.

The current I which flows round the loop, is given by

$$I = V_1/(Z_1+Z_2) \qquad (1)$$

and the detector open-circuit voltage, V_2, is given by

$$V_2 = \frac{V_1}{2} - IZ_1 = \frac{V_1}{2} - \frac{V_1Z_1}{Z_1+Z_2} = \frac{V_1}{2}\left(\frac{Z_2-Z_1}{Z_2+Z_1}\right)$$

$$\text{or } V_2 = IZ_2 - \frac{V_1}{2} = \text{the same} \qquad (2)$$

$$\text{Thus } V_1/V_2 = 2\,(Z_2+Z_1)/(Z_2-Z_1) \qquad (3)$$

Apart from the factor 2, this is just what we require for the determination of the return loss of Z_1 against Z_2, or Z_2 against Z_1. We can write

$$20 \log \left|\frac{V_1}{V_2}\right| = 20 \log \left|\frac{Z_2+Z_1}{Z_2-Z_1}\right| + 6 \text{ dB}$$
$$= (\text{R.L.}+6) \text{ dB} \qquad (4)$$

Before going on to discuss the direct use of this bridge circuit we may, I feel, dispose of another mathematical question. Suppose that we write the return loss as 20 log r. Then

$$r = |(Z_2+Z_1)/(Z_2-Z_1)|$$
$$= \left|\left(\frac{Z_2}{Z_1}+1\right)\bigg/\left(\frac{Z_2}{Z_1}-1\right)\right| \qquad (5)$$

Now either or both Z_1 and Z_2 may be complex, and we can write $Z_2/Z_1 = x+jy$. Thus

$$r = |(x+1+jy)/(x-1+jy)|$$

which gives us $r^2 = [(x+1)^2+y^2]/[(x-1)^2+y^2]$

or $r^2(x^2-2x+1)+r^2y^2 = x^2+2x+1+y^2$

i.e. $(r^2-1)x^2-2(r^2+1)x+(r^2-1)y^2 = 1-r^2$

$$\text{or } \left(x-\frac{r^2+1}{r^2-1}\right)^2 + y^2 = \left(\frac{r^2+1}{r^2-1}\right)^2 - 1$$
$$= \left(\frac{2r}{r^2-1}\right)^2 \qquad (6)$$

This is just the equation of a circle with radius

$2r/(r^2-1)$ and centre at .. (7)

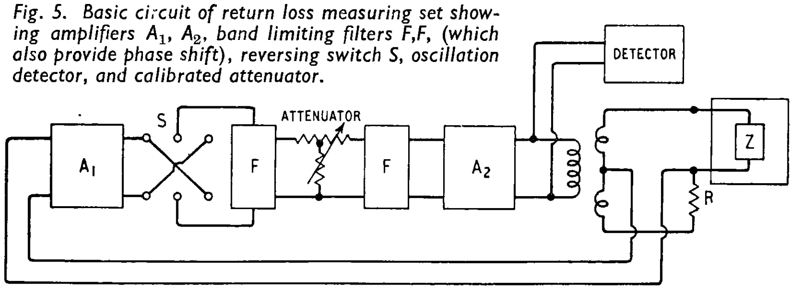
$x = (r^2+1)/(r^2-1),\ y=0$ (8)

Remembering that x and y in equation (6) above are just the real and imaginary parts of the impedance ratio Z_2/Z_1, we see that if we measure the return loss, which means that we determine r, we know only that the relationship between x and y is such that equation (6) is satisfied. The resistive component may be the wrong amount, or it may be correct, but with some unwanted reactance. These various possibilities affect the phase of the reflected signal, while we are concerned only with its size.

Having dealt with this bit of algebra, which we shall make more use of later, let us consider the problem of measuring the return loss just as a number. Look back now to Fig. 4 and equation (4). Suppose that across AB we connect the input of an amplifier, assumed to have a very high input impedance, and that the output, assumed to have a very low impedance, is connected across CD. If the gain of the amplifier is adjusted to be a very small amount greater than (R.L. + 6) dB we have satisfied one of the two conditions required for oscillations to build up from the ordinary circuit noise. If the gain is just less than (R.L. + 6) dB such oscillations will not build up.

This gain condition is, of course, not sufficient to

Fig. 5. Basic circuit of return loss measuring set showing amplifiers A_1, A_2, band limiting filters F,F, (which also provide phase shift), reversing switch S, oscillation detector, and calibrated attenuator.



ensure oscillation: it is necessary also that the signal should suffer the correct phase shift in its passage through the system. Under steady oscillation conditions the signal must, in fact, go through exactly $2n\pi$ radians phase shift in a complete traversal of the circuit. This involves us in some special design problems which we shall now discuss.

The designer of an amplifier for this kind of test will naturally wish to use negative feedback to stabilize the gain of the amplifier and thus avoid the need for its frequent recalibration. A consequence of the use of negative feedback is that the phase shift through the amplifier will be very nearly the same at all frequencies away from the edges of the pass-band. This puts a very severe restriction on our chances of finding the correct phase for oscillation in the particular region in our frequency band where the return loss is lowest (i.e. worst), which is where we are most interested in measuring it. It is only reasonable, however, to use filters to define our frequency band. These filters are our salvation from the point of view of phase, because each half-section we use gives us a phase shift across the band of 90°. Thus a not unreasonable combination of two sections of low-pass and two sections of high-pass filter will assure us of two test frequencies at any given phase, while a reversing switch anywhere in the loop will give us two more. Whether this is sufficient or not depends on the sort of impedance we are going to test. If it varies rapidly we may need more test points, though the phase shift in the bridge itself will help us: if it is a pure resistance it does not matter much at what frequency the test is made.

In some commercial designs of return loss tester additional phase shift is provided as a side product of the need to introduce these filters, and to adjust the gain. The amplifier is split into two portions, each provided with negative feedback. The feedback does not embrace the output transformer of the first amplifier or the input transformer of the second. The purpose of these transformers is to establish a convenient impedance level for the filters which are connected between the amplifiers; and they offer a very useful contribution to the phase characteristic of the whole system.

The block diagram of a return loss tester of this kind is shown in Fig. 5. The oscillation detector may be one of a variety of devices. A simple diode and meter, a pair of headphones if the system is for audio frequency use, or a tuning indicator valve, are three possibilities which spring to mind. An instrument of this kind can easily provide a discrimination of one decibel. Moreover the calibration is very easily checked using standard resistors, and these can be readily built in. Such an instrument is, indeed, just what it should be; straightforward, easily checked, and generally suitable for providing the yes-no discrimination needed in routine testing.

For the designer, as we have already seen, this information is not sufficient. He needs to know the actual value of the return loss in order to correct his design. One available method, which I have never seen used or described, is to apply to the bridge network of Fig. 4 a band-limited noise input as V_1, connect an r.m.s. reading instrument to measure V_2, and then fiddle about with resistance and capacitance boxes across Z_1 or Z_2 as required to get the lowest value of V_2. This technique, described rather slightingly here, would be a possible test room approach to a situation where closer return loss tolerances than normal production permits are needed, subject to an over-riding limitation on the complexity of the correcting network. The most likely example I can bring out of the hat where this technique would be of use, is an audio-frequency amplifier with an input transformer using a high permeability alloy core which for economic reasons has been pushed slightly beyond the reasonable design limit. I do not doubt that there are other examples of just-over-the-edge adjustments.

Normally, however, the designer must measure the return loss at a number of points in the working band. Equation (5) and the results which follow from it lead us to the conclusion that the normal technique will probably be to use an impedance bridge. We may, however, find it convenient to measure admittances, especially at high frequencies. If so, we have:

$$r = \left|\left(\frac{Z_2}{Z_1} + 1\right)\Big/\left(\frac{Z_2}{Z_1} - 1\right)\right| \qquad (9)$$

$$= \left|\left(\frac{Y_1}{Y_2} + 1\right)\Big/\left(\frac{Y_1}{Y_2} - 1\right)\right| \qquad (10)$$

$$= \left|\left(\frac{Y_2}{Y_1} + 1\right)\Big/\left(\frac{Y_2}{Y_1} - 1\right)\right| \qquad (11)$$

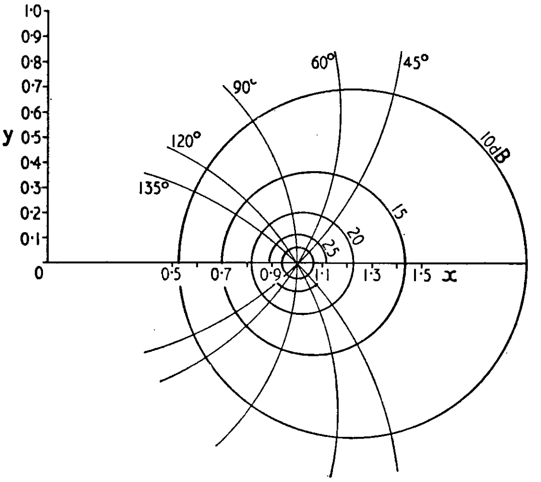


Fig. 6. Return loss contours and orthogonal phase circles for normalized impedance or admittance. (For a fuller construction use Table 13, p. 60 of Mole, "Filter Design Data" (Spon, 1952), or equations 7 and 8).

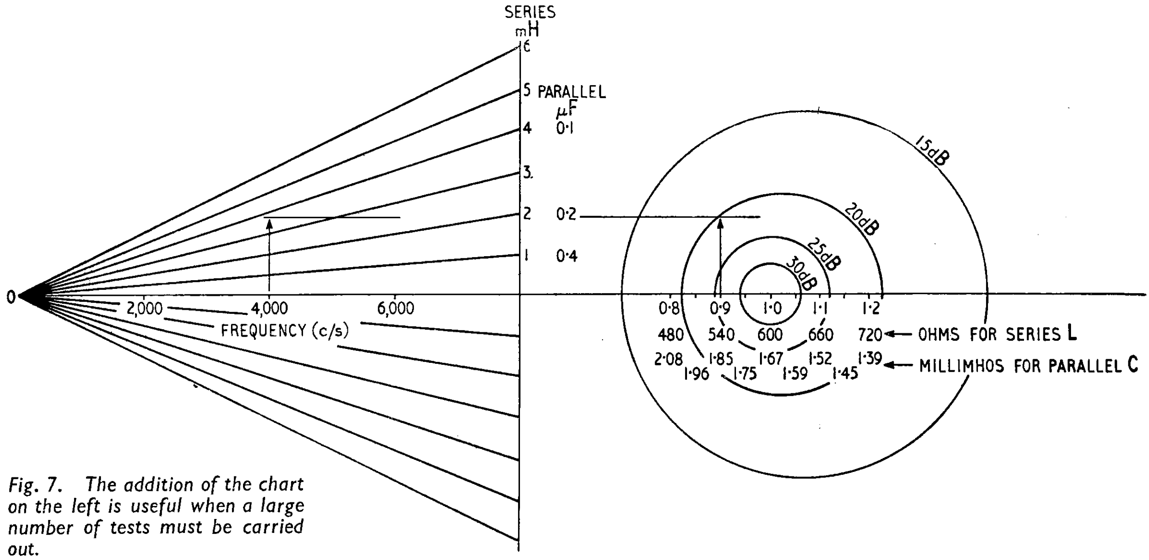


Fig. 7. The addition of the chart on the left is useful when a large number of tests must be carried out.

the only point being that in going from (10) to (11) we have concealed a phase shift of 180°.

The results which were obtained above as equations (7) and (8) are incorporated in Fig. 6. On this diagram, on the rectangular co-ordinate system we plot a trace of the normalized impedance or admittance. We can then read off the return loss from the system of circles, and we can also see where our impedance is going wrong, either through its reactive behaviour, or through a basically wrong value of resistance level. What is more, we can see where it goes wrong most, so that it can be corrected stage by stage. With some experience it is easy to interpret traces on Fig. 6 and to devise suitable correcting networks.

Where a large number of tests are to be carried out within a prescribed frequency range and at a fixed impedance level, it may be worth while to construct the special form of combined impedance and return loss chart shown in Fig. 7. This particular one is suitable for the classic 600-ohm audio frequency case. The example marked in shows that an impedance consisting of 540 ohms in series with about 3.8 mH will give a return loss of 20 dB at 4,000 c/s. As we have seen, these charts may be used for admittances or impedances, so that we can consider $R + j\omega L$ or $G + j\omega C$ equally conveniently. C may, of course, be negative: I cannot think offhand of a bridge which gives negative values of L.

There remains one measuring technique for return loss which is of value in some special video frequency problems. If we wish to transmit 1 μsec pulses say along a line which must be well-matched, we can check the matching by means of the pulses themselves. All we need to do, and this does not mean there are no experimental difficulties, is use a length of cable equivalent to about 1 μsec of travel (giving us 2 μsec go and return), and examine the signal for echoes. This method is used for looking at impedance irregularities in cables, and suitable pulse generators and oscilloscopes can be obtained for it. It is rather a "made-to-measure" approach, because the cable itself probably will not have exactly its nominal impedance, so that, for example, you may be matching to 80 ohms instead of 75 ohms.

Not much more can be said about return loss in a general survey. As might be expected the return loss chart of Fig. 6 has come to look very like the Smith chart. Which approach is the more useful in any particular problem is a matter to be decided by experience, but a rough guide is probably that return loss is more appropriate whenever the system is big enough for echoes to be separated out: if I sing in the bath, that's standing waves; if I shout at a distant cliff, return loss.

CLUB NEWS

Birmingham.—An air traffic control officer from Elmdon airport will talk on air traffic control at the meeting of the Slade Radio Society on December 6th. The club meets at 7.45 at the Church House, High Street, Erdington. Sec.: C. N. Smart, 110, Woolmore Road, Erdington, Birmingham, 23.

Brighton and District Radio Club, which operates station G3EVE, continues to meet at the Eagle Inn, Gloucester Road, on Tuesdays at 8.0, where visitors and prospective members are welcome. Sec.: R. Purdy, 37, Bond Street, Brighton, 1.

Northern Mobile Rally.—Plans are being made for a mobile rally centred on the West Riding for April 27th. Offers of support should be sent to N. Pride, secretary of the Spen Valley & District Radio & Television Society, 100, Raikes Lane, Birstall, W. Leeds, Yorks.

Nottingham.—The Amateur Radio Club of Nottingham, G3EKW, meets every Tuesday and Thursday at 7.15 at Woodthorpe House, Mansfield Road. The programme includes constructional work, morse training, lectures and discussions. Sec.: F. V. Farnsworth, 32, Harrow Road, West Bridgford, Nottingham.

Pontefract.—Meetings of the Pontefract Area Transmitting Group are now held at the Queen's Hotel, Pontefract, on the first, third and fifth Thursday of each month. The club transmitter, G3FYQ, has been installed at the hotel. Sec.: W. Farrar, G3ESP, 6, Hemsworth Road, Ackworth, Pontefract, Yorks.

Wellingborough.—Members of the Wellingborough and District Radio and Television Society will debate the statement "That the days of radio are numbered" at their meeting on December 12th at 7.30 at the Silver Street Club Room. Sec.: P. E. B. Butler, 84, Wellingborough Road, Rushden, Northants.

Choke or Capacitor Input?

Significance of the Two Systems in Power Supplies

By "CATHODE RAY"

AMONG requests received from readers is one for an explanation of the why and wherefore of swinging chokes. Resisting the temptation to invent an analogy between them and swinging cats (or even pirates) I will go straight into a comparison between the two diagrams presented as Fig. 1. A period of 15 seconds is allowed for reaching the conclusion that they both represent full-wave rectifier circuits, and that (b) is exactly the same as (a) except that C_R is missing. Those who are not well up in the design of such circuits might suppose that the only real difference was that the d.c. output from (b) was less well smoothed; a deficiency which could probably be made up by increasing the capacitance of C, and certainly by adding another choke-and-capacitor filter stage. Actually, however, the two circuits work on entirely different principles and have different characteristics. In particular, the choke L in (b) has to be of a special kind, commonly known as a swinging choke, quite different from the one in (a).

Circuit (a) is the arrangement commonly used for supplying h.t. current to small power amplifiers, etc., from an a.c. supply. C_R acts as a reservoir. If no current is being drawn off it charges up during the first few cycles to the *peak* voltage of each half of the transformer secondary coil. This state is illustrated in Fig. 2(a), which covers one complete a.c. cycle. Current cannot be shown on this diagram because there is none going either in or out.

When current is drawn by a load it starts to discharge C_R, as indicated by the downward slope from A to B in Fig. 2(b). C_R can only recharge when the transformer voltage rises above its own voltage, thereby providing a small balance to drive current

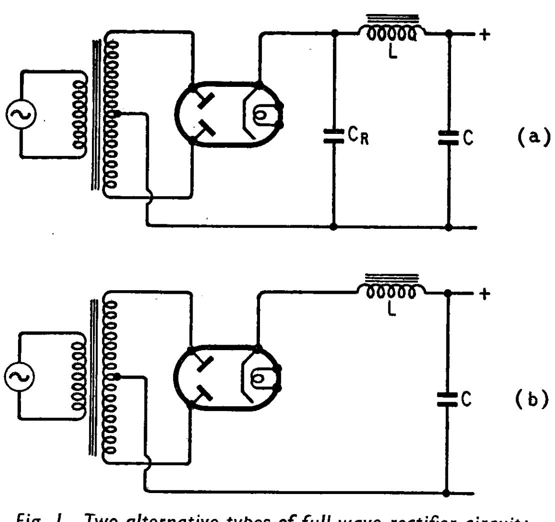


Fig. 1. Two alternative types of full-wave rectifier circuit: (a) capacitor input, and (b) choke input.

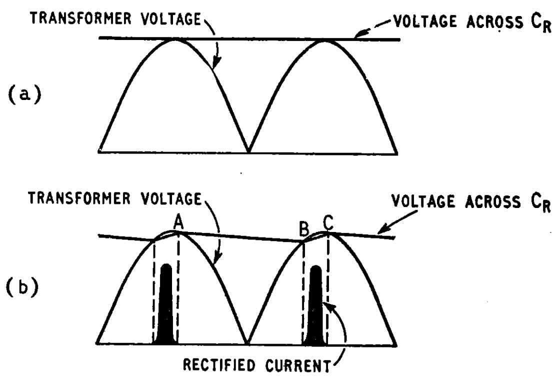


Fig. 2. Diagrams showing the working conditions of a capacitor-input circuit, when (a) there is no current, and (b) load current is being taken.

through whichever half of the rectifier is receiving it. During this phase, marked B to C, C_R has to receive enough current to keep the load supplied continuously throughout half a cycle.

This is where the designer is faced with a dilemma. If he makes C_R small it will lose voltage rapidly between a.c. peaks, the result being a much lower average output voltage at full load than at no load. In technical language, it has bad regulation. It follows too that there is a very large ripple on the output voltage, necessitating much smoothing. If on the other hand he makes C_R large enough to hold the output voltage well up, B comes nearly to the voltage peak, so the period represented by BC is only a small fraction of the half-cycle (AC) and the peak current through the rectifier is therefore many times greater than the steady load current. This is bad for the rectifier, unless an abnormally large sized one is used. It is also bad for the transformer, unless a large and expensive model is used, because a pulse waveform has a much greater r.m.s. value—which is what counts in heating the windings—than the mean value, which is the useful output.

One puts up with these inconveniences when the amount of power to be supplied is so small that the extra cost of the components is not worth seriously bothering about, and especially when the load current is fairly constant, as it is for example when it consists of a Class A amplifier. The current peak can if necessary be kept within reasonable bounds by means of a resistor in series with the rectifier. And the system does have the advantage that the output voltage can be a fairly high percentage of the peak input voltage.

But for large power amplifiers, say 50 watts or more, the extra cost of the rectifiers and transformer on account of the highly peaked current waveform is serious. What is perhaps more serious is that high-power amplifiers often work in Class B (or C), so the current drawn is liable to fluctuate between wide limits. The steep fall-off in output voltage when the current drawn increases—in short, the bad regulation—is then a most undesirable feature of this capacitance-input power supply system.

Compare the choke-input system, Fig. 1(b). Let us suppose that the inductance, L, of the choke is large enough to keep the current through it practically constant. Then the output voltage across the smoothing capacitor C must be practically constant and can be represented by a horizontal straight line. On the rectifier side of the choke the voltage (neglecting the loss of volts in the rectifier when it is conducting) consists of the half-cycles seen in Fig. 2. So the voltage across the choke must be the difference between these semi-sine-waves and the constant voltage. The question is, how high up in Fig. 3 must we draw the horizontal line to represent the constant output voltage?

If we neglect the resistance of the choke and assume it is purely inductive, the voltage across it must be entirely alternating, with no d.c. component. This means that its average each side of its zero line is equal. The horizontal output-voltage line can be regarded as the zero line for the choke voltage, which is then represented by the half-cycle waveform above and below it. To be purely alternating, the shaded areas below the line must be equal to those above. This is the same thing as saying that the height of the horizontal line must be equal to the average height of the half-cycle waveform. The books show us that this height is $2/\pi$ or 0.64 times the peak height, which we call V_{max}.

Since we know that the voltage across an inductance L is equal to L times the rate at which the current through it is changing, we can find the current waveform. Its slope at any point must be proportional to the shaded voltage, so is something like Fig. 4.

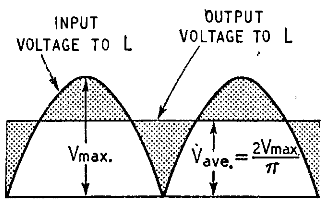


Fig. 3. Approximate voltage relationships in a choke-input circuit with very large choke inductance, when some current is flowing.

At this stage you may object that we were supposed to assume a constant output current and here I am showing it varying. I would point out however that we assumed it was *practically* constant, which means that any variation is small. So Fig. 4 represents a small ripple on a relatively large constant current. There *must* be *some* ripple, to generate the shaded voltage across L.

With our simplifying assumptions the output voltage is as shown in Fig. 3, regardless of the amount of d.c. drawn by the load. So the choke voltage, and therefore the current ripple needed to induce it, is the same at all load currents. In practice an increase in load current does drop the output voltage slightly, because it has to pass through the neglected resistances of choke, rectifier and transformer. Provided these are kept low, the output voltage remains steady at nearly 0.64 times the peak value over a wide range of output current, instead of varying steeply as in the capacitor-input system.

In practice, L cannot be so enormous that the

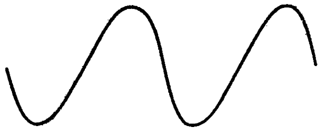


Fig. 4. Waveform of ripple current corresponding to the voltage waveform in Fig. 3.

ripple current is negligible. It may be fairly small compared with full load current, but if the load current is reduced sufficiently a point will be reached where it is not as big as the ripple, so current will cease altogether at the troughs of the ripple. During these periods of interrupted current (twice per a.c. cycle) L obviously cannot give rise to any voltage whatsoever and our theory breaks down. In the limit, when there is no load current at all, L might as well not be there, and C tends to take the place of C_R in Fig. 1(a), so that voltage across it builds up to the peak level.

The relationships between output voltage and load current therefore work out as in Fig. 5, where (a) is the capacitor-input curve and (b) the choke input. The " critical load " for (b) is the load current which is only just enough to be continuous in spite of the ripple. At smaller load currents the output voltage soars up towards peak value, and at larger currents it falls gradually owing to the resistance of the rectifier, etc. The steeper fall of (a) is because of the effect explained in connection with Fig. 2.

One of the objectionable features of (a) is that if current is not being drawn—for example, while valves are warming up—the voltage rises about 40% above its full-load level, so all the components concerned have to be rated accordingly. The choke-input system can be freed from this disadvantage if its load current is never allowed to fall below the critical point. This can be ensured by a suitable resistor connected in parallel with C and known rather unpleasantly as a bleeder. Such a device would be wasteful if the current taken by it—at least equal to the critical load current—was not small compared with the full load current; say at most a tenth and preferably less than that. So the requirement for L is that it must be large enough for the critical load current to be of this order.

An approximate calculation—given at the end, in case anyone is interested—shows that the critical inductance, which is the minimum inductance needed to ensure continuity of current, and which we will call L_c, is equal to the critical load resistance (R_c) divided by $6\pi f$, where f is the supply frequency to the full-wave rectifier. At $f = 50$ this reduces to $L_c = R_c/940$. To take an example, suppose the output voltage (at the critical load) is 500, and one doesn't want the critical load to be more than 10mA. Then $R_c = 500/10 = 50\text{k}\Omega$. Assuming $f = 50$ c/s, $L_c = 50{,}000/940 = 53$ henries. If the full load current is something like 150 or 200mA, that is a formidable inductance to provide, especially if (in order to realize the benefits of the system) its resistance has to be kept low.

Fortunately, however, there is no need for its inductance to be anything like 53H at full load. 5H would be more than enough to ensure continuity of current. In the capacitor-input system, the important thing is to ensure adequate smoothing inductance at full load current, and to avoid saturation of the choke core a gap must be left in it, which necessitates more turns to keep up the inductance and therefore more resistance or higher cost. But the choke in the choke-input system can be allowed to saturate quite a lot at full load provided it gives a high inductance at critical load. I am not certain of the origin of the description "swinging"* for this kind of choke, which was used at least as far back as 1929, but apparently it refers to the variation of inductance when the d.c. through it is varied.

That is not the only difference between it and the ordinary smoothing choke. Fig. 3 shows that the peak voltage across it at all working load currents is about equal to the full output voltage. So the insulation of the windings must be adequate.

One way in which the critical current can be reduced (or alternatively the critical inductance reduced) is to tune the choke to the fundamental ripple frequency, which is twice the supply frequency. This is done by connecting a suitable capacitor across L. Admittedly it by-passes the higher ripple frequencies, but they can easily be dealt with by the subsequent smoothing filter. Suppose in the previous example we cut down the 10mA inductance of the choke to 20H. This alone would not provide enough impedance at 100 c/s to keep the fundamental ripple current below 10 mA peak, but it could be made to do so by means of about 0.127 μF in parallel with it.

The rectifier used in conjunction with choke-input is usually a gas-filled type, because that has negligible slope resistance and so promotes the constancy of output voltage. The absence of current peaks much greater than the full load current means that quite a small rectifier can handle considerable power. Unless some historian can prove the contrary, it may be taken that choke-input was introduced specifically to enable the best use to be made of the then new gas-filled rectifier.

Summarizing

The capacitor-input system gives bad regulation and requires higher rated transformer, rectifier and smoothing capacitors than choke-input. In low-power apparatus, especially for more or less constant load current, these disadvantages, being small, may be outweighed by the advantage of higher output voltage. The greater the power to be supplied the more likely the choke-input system is to show an overall economy, and for Class B and similar requirements it is far the better. The choke must have a low resistance and a high inductance at low current, and be capable of standing peak voltages of the same order as the maximum output voltage. It is helpful to tune it by parallel capacitance to minimize the critical load current, below which the output voltage rises very steeply.

Lastly, here is the derivation of the $L_c = R_c/6\pi f$ formula. In Fig. 6, I_d is the d.c. or load current and I_a is the peak ripple current at its fundamental frequency, which is $2f$. At the critical value of I_d it is equal to I_a. Denote the peak alternating voltage by V_{max}; assuming sine waveform, its average value is $2V_{max}/\pi$. The load current I_d is equal to this divided by the total d.c. resistance, of load plus choke, rectifier and transformer. At the critical I_d these additions are normally small enough to neglect compared with the critical load resistance R_c, so critical $I_d \simeq 2V_{max}/\pi R_c$.

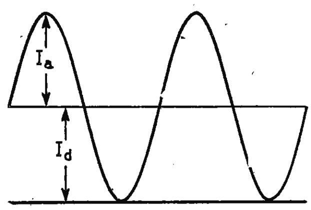


Fig. 6. Fundamental ripple and load currents at the critical point.

Now the peak alternating component of the full-wave rectified " input voltage to L " in Fig. 3, at its lowest frequency (which is $2f$, the fundamental ripple frequency) is $4V_{max}/3\pi$. Again neglecting the rectifier etc. resistance, and also the impedance of C at that frequency, we have $I_a \simeq 4V_{max}/3\pi X_L$, where X_L is the reactance of the choke at frequency $2f$, so is $4\pi f L$.

Putting $I_d = I_a$, which is the critical condition:

$$\frac{4V_{max}}{3\pi \times 4\pi f L_c} = \frac{2V_{max}}{\pi R_c}$$

which simplifies to

$$L_c = \frac{R_c}{6\pi f}$$

* The earliest reference I know is in an article by F. S. Dellenbauch and R. S. Quimby in Q.S.T., March, 1932.

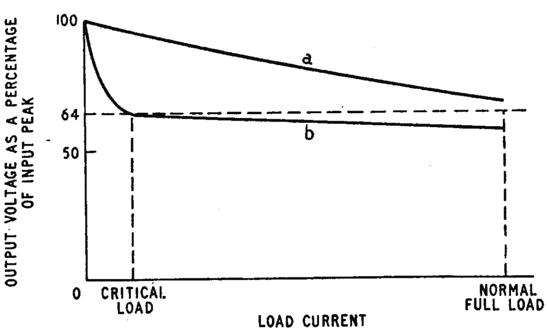


Fig. 5. Comparison of output voltage/current curves for (a) capacitor input and (b) choke input systems.

British Standard Specification for Ebonite

THIS is a revised version of the war-time emergency standard specification BS234 of 1942 and it covers three groupings of ebonite.

The specification covers ebonite in the form of sheets, rods, tubes and mouldings suitable for electrical and certain electronic applications. It also covers the loaded type of ebonite specified in the Wireless Telegraphy Board specification No. K109.

It lays down standards and tolerances for thickness and size of sheets; thickness, length and diameter of tubes, and length and diameter of rods.

Section 3 defines the nature of electrical tests that shall be applied, these cover permittivity and power factor.

Appendix C is concerned with tests at audio frequencies and Appendix D permittivity and power factor at radio frequencies. In the latter case tests are made at approximately 1 Mc/s. A circuit diagram of an approved test bridge is included.

The revised specification, which is known as BS234: 1957, covers 24 pages and costs 6s (6s 9d by post). Copies are obtainable from British Standard Institution, 2, Park Street, London, W.1.

LETTERS TO THE EDITOR

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

Loudspeakers in Parallel

REFERRING to the interesting article "Loudspeakers in Parallel" by J. Moir (October, 1957), I assume the author is dealing with directional speakers when he says that no increase of apparent source size is achieved by using two or more in parallel; if this assumption is correct, I agree with Mr. Moir's findings.

But if we use omni-direction speakers the results are quire different, especially in concert halls. We have found that spacing four omni-directional speakers wide apart on the platform not only broadens the apparent source size, but also subdues hall resonance. (Carnegie Hall, New York—in spite of its reputation—possesses the biggest bass "honk" in the world, and the effect of spacing loudspeakers on the platform is quite magical.)

Mr. Moir speaks with authority on cinema installations, in which horn loading gives an impression of efficiency, due mainly to strong directional effects; but if we watch and listen to an orchestra we must be impressed by the largely omni-directional quality of the sound from the various instruments. I am convinced that the only way to recapture this effect in reproduction is to use omni-directional speakers, and any success we have had in this field has been due mainly to a realization of this simple truth.

As regards l.f. improvement obtained by using parallel speakers close together, how right Mr. Moir is! Two speakers on a baffle give astonishing bass; the l.f. output is double, and the risk of distortion from overloading is halved: in fact we get something for nothing in the audio region where it is usually wanted the most.

G. A. BRIGGS,
Idle, Yorks. Wharfedale Wireless Works, Ltd.

MR. MOIR'S enthusiasm for so-called stereophonic reproduction leads him in your October issue to a piece of special pleading which does not fully present what can be achieved by effective sound distribution from a single-channel source under domestic conditions. Mr. Moir's observations are confined to twin loudspeakers spaced 8-10ft apart with the listener moving laterally at an unspecified distance from the source.

I submit that his conclusion that an increase in the apparent size of the source cannot be achieved without "stereophony" is insupportable without full consideration of all the following factors:—

(a) Multiple loudspeaker placement not necessarily confined either laterally to the position considered most advantangeous to stereophony; nor vertically to floor level whereby the apparent height of the source becomes fixed unsuitably; nor to two in number since even enthusiasts for "stereophony" advocate at least a third speaker so placed as to fill the central "hole"; nor to the specified position on the vertical axis—since rotation causes marked alteration of the results achieved.

(b) Control of the frequency range of individual speakers up to (with two only) complete elimination of the bass range on the one side with or without elimination of the treble range on the other.

(c) The location of the observer along the axis, including a position *between* two speakers.

(d) The type of reproduced sound, particularly speech—when the greatly enlarged source (!) renders the method unsuitable. The superiority of multiple closely spaced small cones in the bass range and the diminution of eigentone excitation by strategically placed ancillary speakers (the latter not mentioned by Mr. Moir) are of course not relevant to the present discussion, which is concerned solely with the possibility of effective sound distribution in the domestic listening area without resort to multiple channels. A. H. BARZILAY.

Stellerbosch, S. Africa.

Projection Television

I WILL admit I am staggered by A. G. Tucker's claim (October issue) that he can view a forward projection picture from a modified Philips 1800 chassis, with 450 watts lighting in the room.

The black level of the picture can only be that of the light reflected from his aluminiumized screen, so his picture contrast range must be from white to a shade of grey, even if the 450 watts is indirect lighting. I am certain that satisfactory daylight viewing is impossible, and I speak from experience.

I have sold and installed several forward projection models, always against my advice to the customer, and have had several dissatisfied customers in consequence. Apart from the insufficiently lit picture, there is all the trouble of setting up the projection console in the centre of the room, with trailing mains lead and aerial lead, while the illusion of reality is killed by the sound coming from the console instead of the screen.

The back projection model is quite another matter, and, as typified by the Ferranti 20K series, is, in my opinion, the best of all television pictures, and far less tiring to the eyes than direct tube viewing. If viewed against the light from the window, even on a bright sunny day, the picture is quite acceptable, and at night, a correctly optically focused 24in screen picture compares more than favourably with any direct vision receiver, with the added advantage that the line structure is practically unnoticeable. Overall focus is far superior to any 21in tube receiver I have handled, and the picture has a beautiful photographic quality.

Before the advent of the 17in screen, we sold large numbers of back projection models, but nowadays there is not sufficient public demand, and manufacture has apparently ceased. Perhaps we shall see a renaissance of the projection television receiver when colour transmissions begin?

O. V. WADDEN,
Hounslow. Wadden & Hill, Ltd.

MR. O. V. WADDEN, in his September letter, is evidently unaware of the "Daylight" type of viewing screen recently developed, which does in fact permit of daylight viewing of film and projection television pictures without need to darken the room. Developed precisely to meet the difficulty in situations where black-out may be undesirable or impracticable, this screen requires no shielding or other special precaution in ordinary daylight conditions, and will under those conditions provide a picture comparable in contrast and brilliance with the same picture shown in darkness.

"Free Grid's" projected and future receiver (July issue), therefore, makes no kind of nonsense except that, the "Daylight" screen being a translucent or rear-projection one, the picture will appear in the adjoining room! A simple mirror arrangement, however, suffices to get it back again, and "Free Grid" is in fact predicting a development which I can assure your correspondent has already taken place and is actually in use in many schools and other specialized applications to-day. A more practical technique, however, is to fit the projector with a short-focus lens and house it in one cabinet or wall-cupboard with the mirror and screen itself, and I have in fact been using this arrangement for some time.

I have two of these screens, which are black or nearly so, apparently unbreakable, and can be used for either TV or film projection with projectors of quite moderate power and, being colour-corrected for incident light over most of the visual spectrum (actually 4,500-6,500 A), for monochrome and colour projection also. And how near the mark "Free Grid" actually came (albeit retrospectively!) is suggested by tests recently carried out by the B.B.C. at Lime Grove, in which a spotlight powered by a high-intensity arc of 2½ kW at ten yards failed to quench the *colour* picture on one of them with 750 watts in a projector using single-frame 35mm Kodachrome film—an apparently miraculous result possibly accounted for by the name "Black Magic" or the clue "regenerative" accompanying it, since the stilb[1] value of the "quenching" beam exceeded that of the projector by a factor of the order of 4, and its intensity in terms of foot-candles by considerably more.

Whatever the reason, which is in fact the novel one that the screens exhibit *gamma-plus* characteristics, i.e., maintain their contrast values under conditions hitherto thought to be impossible, they are effectively "blind" to ambient light of any intensity likely to be found in the average classroom or living room and remain unshaken by conditions intolerable to any front-projection or ordinary back-projection screen, and it is almost startling to show a picture in the dark and suddenly switch on several hundred watts of light without apparent effect whatever.

But the makers exclude direct sunlight on the not unreasonable ground that whereas the intensity of the best tungsten projector lamp at full loading is under 20 stilb, that of the sun is of the order 200 stilb (that at Lime Grove was *circa* 60 stilb). This suggests the conclusion, confirmed in practice, that for optimum results the screen should be as small as possible consistent with acceptable magnification, because the output of even the best high-intensity c.r. tube in terms of lumens falls considerably short of that of a 1,000-watt projector lamp, and my own experience indicates 4 sq. ft. as the present upper limit of advisable screen area under average room conditions in daylight, e.g., a mean ambient light level of 12-20-foot candles. And I say *present* because, a true "Daylight" or anti-dilution screen having been developed, the limiting factor has now become the light available at the projector which is by no means likely to remain a static quantity.[2]

To summarize briefly: (a) Mr. Gould is in order; (b) Mr. Elliott is in order; (c) "Free Grid" is in order, but conservative and a few degrees out of phase; (d) Mr. Wadden is a little "off-beam" but now I hope in daylight.

For which scandalous generalization I apologise.

"ÅNGSTROM UNIT."

Hadlow Down,
Sussex.

[1] Stilb = candelas/sq cm; a unit of intrinsic brilliance in a light-source or illuminant.

[2] And is not necessarily limited to that obtainable from the incidence of electrons on the phosphor in a c.r. tube.

Line Scan Ringing

K. G. BEAUCHAMP in his article in the September issue makes a statement that the ratio of the ringing frequency to the flyback frequency is 2.7:1 and not 3:1, due to the booster diode conducting for more than one half cycle of the fundamental resonance. I disagree with this statement for the following reasons.

For a typical design one half cycle of the fundamental resonance is about 14 μsec. For 1½ cycles of oscillation the difference in time between the ratios of 3:1 and 2.7:1 is 1.55 μsec, so if Mr. Beauchamp's statement is correct this will be the time the booster diode conducts in excess of one half cycle of the fundamental frequency. For a typical timebase the difference in potential of the booster diode cathode at the commencement and finish of the flyback is about 25 volts, due of course to the impedance of the valve. Since during the flyback period the peak potential to which the valve cathode rises is some 4,000 V, it is possible to calculate how long the diode conducts in addition to one half cycle of oscillation.

The instantaneous diode cathode voltage $e = 4{,}000 \sin \omega t$

$$\therefore\ 25 = 4{,}000 \sin \omega t$$

$$\sin \omega t = 0.0065 = 0.37^\circ$$

$$\text{Expressed in time} = \frac{0.37}{180} \times 14\,\mu\text{sec} = 0.029\,\mu\text{sec}.$$

This then is obviously not the reason for the ratio of the frequencies being 2.7:1.

If Mr. Beauchamp carefully examines the ringing frequency during the flyback period he will find the first and last quarter cycles are of shorter duration than the centre cycle. This is due to the capacities of the circuit being charged and discharged by the main flyback pulse. For minimum ringing during the scanning stroke exactly 1½ cycles of the oscillation must occur during the flyback period and this is made up of one cycle of the ringing frequency at 2.7 times the fundamental, plus the charge and discharge times of the capacities. This is clearly shown on page 91 of *Mullard Technical Communications*, No. 14, August, 1955.

Mr. Beauchamp also states that with 5th harmonic tuning, better e.h.t. regulation can be expected. This is only true if the e.h.t. is lower for the 5th harmonic condition. For the same value of e.h.t. the regulation with 3rd and 5th harmonic tuning is similar. With 5th harmonic it is necessary to increase the overwind turns and this increases the leakage induc-

tance, which results in a worsening of the regulation.
Mr. Beauchamp gives the credit for this method of tuning the leakage inductance of the line transformer to C. E. Torsch, but the original work was carried out by P. J. H. Janssen of the Philips Company in Holland and is described in Patent Specification 723, 510 the date of the application being December 19th, 1951.

K. E. MARTIN,
Mullard Research Laboratories.
Salfords, Surrey.

X-radiation from TV Sets

I NOTICE that on page 468 of your October issue, it is implied that a television receiver with a 24-inch tube employing 17 kV on its final anode may result in significant X-ray radiation.

My Association has been giving considerable attention to the problem of possible X-ray radiation from television receivers. While investigations are not yet complete, it can be stated that the viewing public has nothing to fear from this source when the set is operated inside its cabinet. Tests made with an e.h.t. voltage of 27 kV and a beam current of 500 μA showed a barely detectable radiation at the front of the safety screen; at voltages below this there was no detectable radiation in a forward direction. At 20 kV and with a beam current of 800 μA, there was no detectable radiation at any point on the outside of the cabinet, even when the safety glass implosion screen was removed.

The indications are that the critical voltage at which X-ray radiation commences to be significant is in the region of 25 kV, although this must be qualified by a number of other factors.

S. E. ALLCHURCH,
Secretary, The British Radio Equipment Manufacturers' Association.
London, W.C.1.

"Do It Yourself" Interference

IN a recent series of weekly programmes in the B.B.C.'s Television Children's Hour Gilbert Davey has shown his youthful audience how to make a simple radio receiver.

The circuit is that of a one-valve regenerative detector—a dangerous source of heterodyne interference at any time and particularly when in the hands of a child whose knowledge of positive feedback is, understandably, limited. The tuning and reaction condensers are of the solid dielectric type so it would not be easy to adjust the set to the threshold of oscillation without contributing even more interference to the already chaotic state of the medium-wave band.

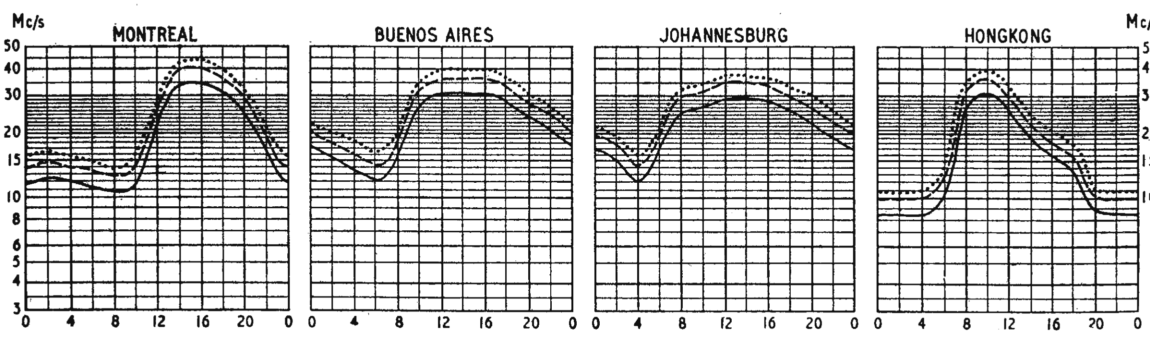
So we have the strange paradox of the B.B.C. Sound Broadcasting Service doing its best to improve reception for its dwindling listening audience and, at the same time, the B.B.C. Television Service giving to hordes of eager youngsters minute details for making an instrument which, basically, is a transmitter capable of ruining reception for thousands of listeners.

It is understood that the response to the Corporation's offer of printed instructions for making the set has been very large which would suggest that the Post Office radio interference sleuths can look forward to a busy season as thousands of one-valve transmitters, with youth at the helm, merrily join in the free-for-all "jam session" on the medium waves.

It is doubtful whether any appeal to the new set owners NOT to oscillate will have any greater effect than Capt. P. P. Eckersley's famous entreaty "PLEASE don't do it" from Two Emma Toc in the early nineteen twenties.

DOUGLAS WALTERS.
Godalming.

SHORT-WAVE CONDITIONS *Prediction for December*



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

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

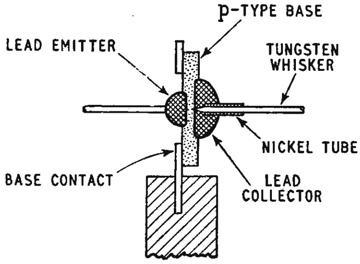
••••••••••• FREQUENCY BELOW WHICH COMMUNICATION SHOULD BE POSSIBLE FOR 25% OF THE TOTAL TIME

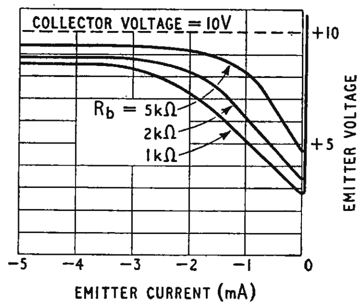
— — — PREDICTED AVERAGE MAXIMUM USABLE FREQUENCY

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

Technical Notebook

New Switching Transistor developed by the German Post Office was described by W. von Münch at the recent International Components Symposium at Malvern. It is constructed rather like an n-p-n alloy junction transistor, with lead-antimony emitter and collector electrodes alloyed on to a high-resistance p-type base. During the alloying process a tungsten whisker encased in a nickel tube is embedded in the collector so that it just penetrates the collector junction. When a resistance is connected in the base circuit the device has a negative-resistance characteristic rather like a point transistor (see emitter input graph).





This gives a regenerative action which produces a rapid switch-over, when the emitter is suitably triggered, from a high resistance condition (right) to a low-resistance condition (left). The electric field set up in the base region by the tungsten whisker accelerates the current carriers and thereby gives a switching time of only 0.1-0.2 μsec. It is notable that this high-speed response is obtained with a transistor whose base region is as thick as that of an ordinary a.f. transistor. Pulse repetition rates of up to 2Mc/s can be handled by the device.

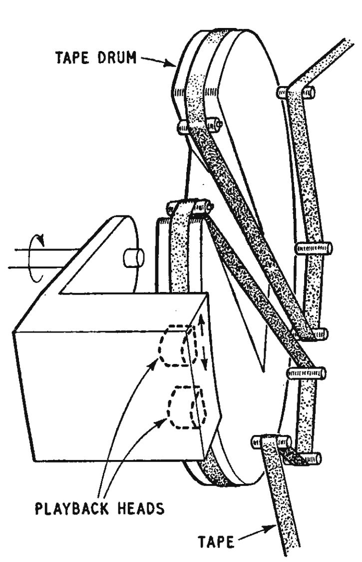
8⅓ r.p.m. Record development was described by Dr. P. Goldmark of the Columbia Broadcasting System Laboratories at the ninth annual convention of the Audio Engineering Society held recently in New York. These records were developed under the sponsorship of the American Foundation for the Blind, and are designed for speech reproduction. This allows the groove amplitude to be the same as that on the 16⅔ r.p.m. records using a ¼-mil radius stylus tip also developed by the C.B.S. Laboratories for the Chrysler car record player (described in *Audio Engineering* for December, 1955). The upper frequency limit is, however, halved, but for speech this limitation is not serious. A 7-in diameter record provides four hours of speech, and a 12in record 10 hours. The same tone arm as in the car record player is used. A viscous fluid in the vertical bearing damps out any tendency for the pickup to move relative to the record when the whole player is moved horizontally, while still providing a bearing free enough to allow the extra fine record grooves to be tracked with a stylus force of only two grams. The pick-up cartridge in the arm is balanced about a horizontal axis, and the arm itself is rigid in a vertical plane, so that vertical movement of the player as a whole also does not displace the stylus from the groove. Moreover, if the pickup is accidentally moved by hand across the playing surface only the stylus force acts on this surface, and this force is so low that any scratches produced are not audible. This is an important advantage for blind users and is also, of course, valuable in the original car record player application.

Half-Century Time Constant is claimed for three 1-μF capacitors, shunted by their own insulation resistance of 1.5×10^9 ohms, which have been on test so far for six years at the Telegraph Condenser Company. At the beginning of the six-year period they were charged to 500 volts and are now still well above 400 volts. The high insulation resistance has been achieved by the use of plastic film dielectrics, which are now tending to replace paper for low leakage applications. Very thin films are desirable to reduce the size of capacitors, and development is proceeding on polystyrene films of only 0.0001-0.00025 inch in thickness. It is expected that capacitors of up to 1μF for operation at a maximum of 50 volts d.c. will be possible using metallized films of this type. These, of course, will be very suitable for transistor circuits.

Analogue Divider produced from a combination of rectangular-hysteresis-loop magnetic materials and transistors used as switches is described by D. H. Schaefer in unpublished report PB111969. The device gives an average output voltage which is the quotient, with correct sign and accurate to ±2.5%, of two input voltages. An extension of the principle to a much more general computing element is discussed, and this gives an output proportional to various functions containing quotients.

Frequency Shift Modulation, a quantized system loosely comparable with frequency shift keying, is suggested as a means of obtaining high quality sound radio transmission through a dispersive medium, such as the ionosphere, in unpublished report PB118806 by L. B. Arguimbau, J. Granlund, E. E. Manna and C. A. Strutt. This follows an account of experiments investigating the possibility of using frequency modulation techniques to establish a transatlantic radio link of local broadcast quality over an ionospheric path. It is concluded that ordinary frequency modulation would not be successful because of the complexity of the ionospheric path.

High-Speed Correlation Computer. —The sketch shows in simplified form the mechanical system of the Ramo-Wooldridge device mentioned in September. A 28-inch length of magnetic tape from the storage reel

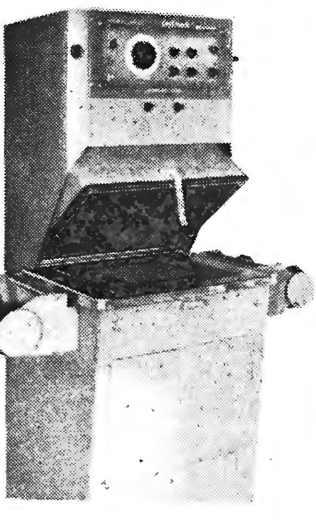


is held stationary on the fixed drum, while an arm carrying the two play-back heads rotates about it. For each revolution the heads are automatically displaced one step by a cam mechanism, the range of travel being from zero displacement to 2.5 inches. A head amplifier is mounted on the rotating arm and its output is fed out by means of slip rings and brushes.

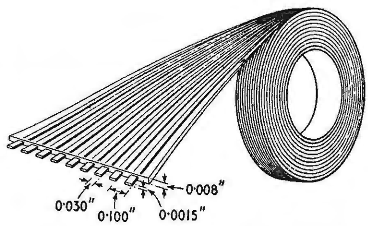
Oxide Film Resistors, using mixtures of tin and antimony oxides, should soon be in commercial production in this country. They are notable for good thermal stability and should be capable of high temperature operation. The films have a high resistance to abrasion which makes them particularly suitable for potentiometer elements, although there is also a high contact resistance between the element and wiper which may prove a disadvantage. In manufacture, the oxide films are prepared by spraying chloride solutions of the tin and antimony on to heated glass or ceramic bases. The process is said to be relatively simple and reproducible, permitting good control over the chemical properties of the film. Examples were shown at the recent International Components Symposium at Malvern and described by G. V. Planer, of Planer Laboratories.

Stone-like Qualities are said to be possessed by an inorganic plastic called Rosite which is now being manufactured in this country by a subsidiary of Plessey. Chemically it is a calcium aluminosilicate with a microscopic grain structure, integrally reinforced with asbestos fibre. It has inherent heat resistance, arc resistance and dimensional stability at high temperatures, and is therefore suitable for many electrical applications.

Electronic Photo Printer.—Below is illustrated the American LogEtronics equipment described in our November 1957 issue (p. 547) which is now being handled and further developed in this country by E.M.I. Electronics.



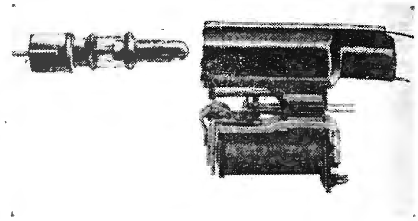
Flat Tape Cable, a new type of multi-conductor cable made by the Tape Cable Corporation of New York, is notable for its small cross-sectional area and low capacitance between conductors compared with equivalent conventional cables. Described in the September, 1957, issue of *Electronic Industries*, the cable is a ribbon-like flexible film of transparent polyester insulation with flat copper conductors only 0.0015 inch thick embedded in it. A 100-ft. roll of 50-conductor tape cable weighs only 2½lb, which is said to represent a saving of 85% in copper over conventional types. The capacitance



between conductors is claimed to be less than 5pF per foot, while earthing alternate conductors reduces this to less than 1pF per foot in free space. The cable is particularly suitable for making flexible connections between chassis or sub-assemblies, such as printed circuit boards, and has been used successfully in applications requiring a continuous flexing on a radius of ¼ inch.

Zinc Capacitor Electrodes are said to be far superior to aluminium for metallized paper capacitors in an unpublished report (PB111715) from the Sprague Electric Company of America. A solid hydrocarbon is considered to be the most suitable impregnant. The temperature characteristics of metallized capacitors are shown to be equivalent to those of foil capacitors, and samples have been found to be satisfactory after 1,000 hours at 85°C and at 1-5 times the rated voltage.

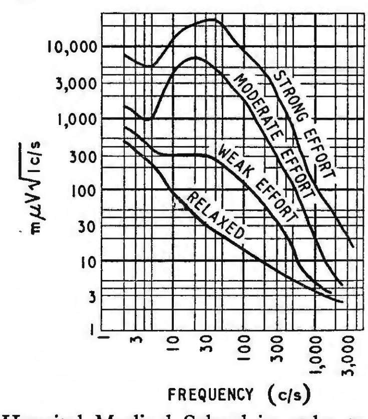
Relay Vacuum Switch recently introduced by Engel and Gibbs is a small evacuated glass tube containing contacts which can be operated by the armature of a miniature relay. Voltages up to 2000V, a.c. or d.c., can be switched in the space occupied by a miniaturized Post Office type relay, with a maximum switching capacity of 2kW. There is no arcing, of course, as the make and break occur in a vacuum. The switch is operated mechanically from the outside through a metal diaphragm, requiring a force of approximately 85 grammes. It is silent in operation and can be used in any position. A switching frequency of 20 operations



per second is possible with non-inductive loads and 3 per second with inductive loads. The actual tube is contained in a plastic case which provides protection and insulation and also positions the device accurately on the relay.

Electrolytic Oxygen Generator has been developed by the U.S. Naval Research Laboratory from a standard commercial nickel-cadmium battery by replacing the nickel oxide plates with sheet nickel ones. Since the cadmium plates do not gas during most of a charge or discharge and the inert plates gas continuously, a single gas is produced in a cell at any time. The battery type of construction is said to be advantageous in both weight and size. Details are given in unpublished report PB121245.

Muscle-Potential Spectra shown below were obtained from the thigh muscle of a man by means of a Muirhead-Pametrada wave analyser when weak, moderate or strong efforts were made to contract the muscle and also when it was relaxed. This experiment was done at Guy's



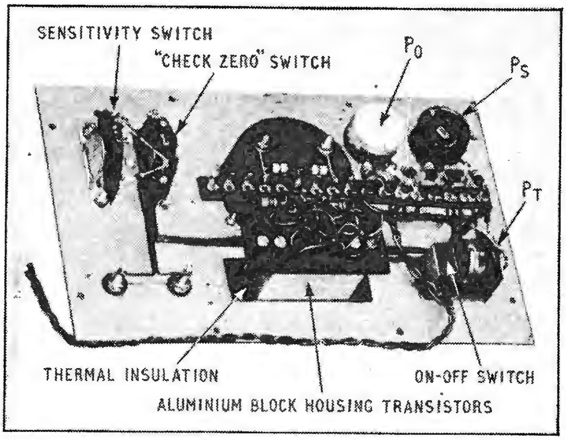
Hospital Medical School in order to establish the frequency band required in the design of an electromyograph amplifier. The most important components associated with the contraction lie between about 10c/s and 600c/s (the values on the vertical axis being proportional to the square root of the power in a bandwidth of 1c/s). There is a discussion on the method of using the analyser on these random waveforms (including frequency analysis of amplifier noise) by A. Nightingale in the October, 1957, issue of the Muirhead journal *Technique*.

Sensitive D.C. Null Detector

General view of null detector.

A Transistorized Galvanometer Giving a Full-Scale Deflection for 50μA

By FRANCIS OAKES,* A.M.I.E.E., A.M.Brit.I.R.E., M.Inst.E., and E. W. LAWSON,* A.M.I.E.E.



Underside view of panel

THE accuracy of measurement obtainable by bridge or potentiometer methods is frequently determined not so much by the accuracy of the standard resistors or voltage sources as by the sensitivity of the null detector available. This is particularly true in the case of routine measurements in production departments, inspection departments and routine laboratories where equipment has to be simple and robust because of its use by semi-skilled operators.

The availability of junction transistors capable of operating at extremely low current levels has made possible a substantial improvement in the design of null detectors in terms of sensitivity as well as mechanical and electrical ruggedness. In addition, the cost of an instrument of the type to be described is less than that of a conventional galvanometer of equal sensitivity, slower response and substantially greater mechanical and electrical vulnerability.

Basic Principles.—Junction transistors are capable of operation as d.c. amplifiers subject to limitations imposed primarily by their saturation currents and base-to-emitter potentials. These parameters are of the order of a few microamps and of about 100mV, respectively, at room temperature. Furthermore, they are subject to substantial changes due to temperature variation, difference in parameter values from unit to unit even of identical type being a further complication. In spite of these limitations, simple transistorized d.c. amplifiers can be constructed which are superior in performance to conventional amplifiers of comparable cost, provided advantage is taken of circuit techniques suitable for minimizing zero drift arising as a consequence of circuit parameter changes. Such techniques are primarily based on the use of balanced long-tail pairs and of stabilization of the operating point of transistors at low voltage and low current levels.

An amplifier embodying these techniques was described in *Wireless World*, November, 1956.† Since then, new high-frequency transistors with smaller junction areas and smaller leakage currents have become available, and advantage was taken of this, by substituting such transistors in place of the low-frequency types originally recommended. With an input impedance of approximately 20kΩ and a current gain of the order of 1,000, feeding into a 50-0-50μA moving-coil instrument, a suitable basic unit is provided round which to build the instrument.

Circuit Arrangement.—The main issue in deciding on circuit arrangements for this type of instrument is to make a suitable choice for the placement of sensitivity controls. In principle, two alternatives are available: (a) attenuation in front of the amplifier, (b) attenuation further along the amplifier chain or at the meter terminals.

Method (a) was chosen for the following reasons: Attenuation in front of the amplifier affords maximum protection from damage by overloading. The amplifier will stand an overload of approximately 1,000 times full-scale deflection. Thus, if the sensitivity is cut to 1/10 and 1/100 to provide alternatives to the most sensitive range, the instru-

* Ferguson Radio Corporation Ltd.

† D. M. Neale and F. Oakes: "Transistor D.C. Amplifier."

ment can accept 1 volt, 10 volts and 100 volts at the input terminals without sustaining damage, whilst a null can still be detected with a discrimination of 20μV, 200μV and 2mV respectively.

Method (b), on the other hand, would offer the advantage of greater zero stability on the attenuated ranges. For use of the instrument as a null detector, this is of minor importance, however, as the final check is always made on the most sensitive range. A complete circuit diagram of the instrument is shown in Fig. 1. The schematic circuits in Fig. 2 indicate the actual input connections at the three sensitivity control settings.

Construction.—The instrument is housed in a small box containing the 50-0-50μA moving coil meter, which is very robust in comparison with a galvanometer of a sensitivity approaching that of this instrument, i.e., 0·05μA full scale.

The sensitivity can be varied by means of a spring-loaded range switch arranged to return to the minimum sensitivity position. The medium and maximum positions can be locked in, if desired, by means of catches on this switch.

For setting up, two zero controls are required, to adjust for open-circuit input and short-circuit input respectively. These adjustments are facilitated by a second switch, spring-loaded to return to normal working position. Moved up, it removes the input signal and short circuits the amplifier input, moved down it opens the input terminals. By this means, zero adjustment can be checked rapidly and without removing the signal source from the input terminals.

In order to minimize zero drifts, the transistors are mounted in holes drilled into an aluminium or brass block and by insulating this block against ambient temperature variations. Each transistor is wrapped with copper foil until a tight fit in the hole.

Before setting up, a few minutes must be allowed for the collector temperatures to settle, after which the zero adjustments can be made and the instrument is ready for use. In case of frequent or continuous use, it may be preferable to keep the instrument permanently switched on; with a total current drain of the order of only 2mA, battery replacement is not a serious problem, and the additional stability and immediate availability for use may well justify the extra cost.

Performance Data:

Sensitivity: 0.05μA full-scale deflection.
1mV full-scale deflection.

Resolution: 10^{-9} amperes.
2×10^{-5} volts.
2×10^{-14} watts.

Zero drift: Short term. Not more than 5% of full-scale deflection for 10 minutes at constant ambient temperature.
Long Term. Depends on ambient temperature changes.

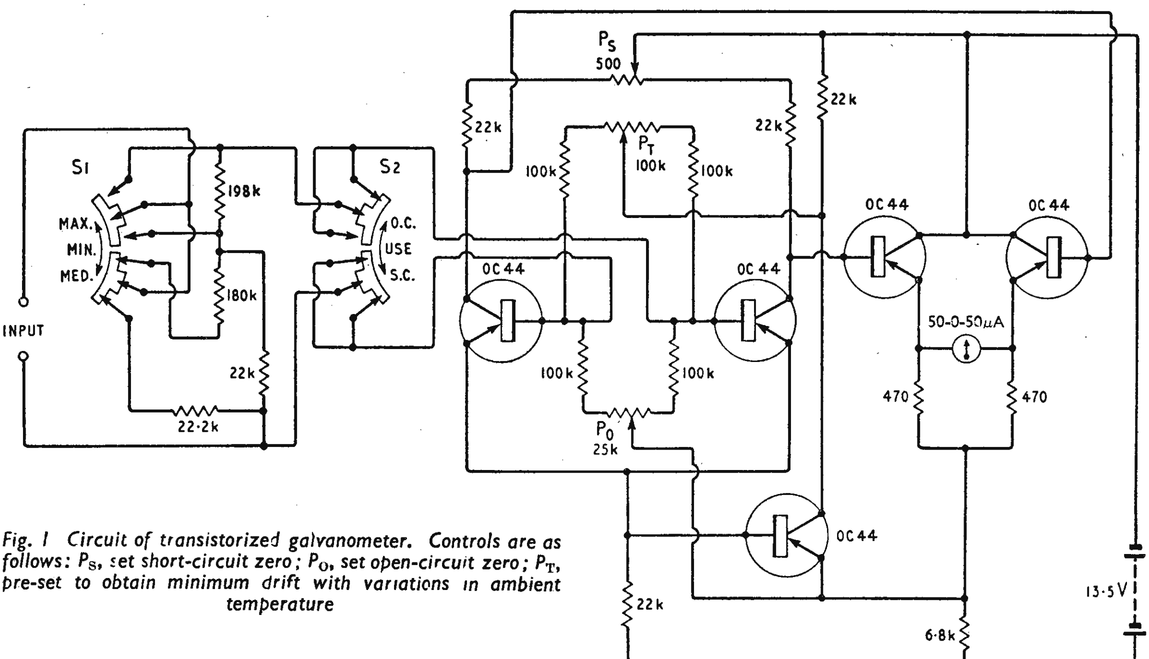


Fig. 1 Circuit of transistorized galvanometer. Controls are as follows: P_S, set short-circuit zero; P_O, set open-circuit zero; P_T, pre-set to obtain minimum drift with variations in ambient temperature

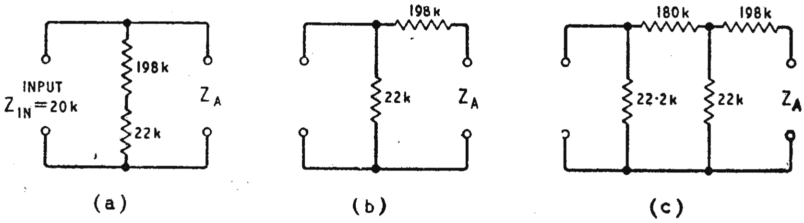


Fig. 2 Attenuator circuit arrangements. (a) Maximum sensitivity, gain 1,000. (b) Medium sensitivity, gain 100. (c) Minimum sensitivity, gain 10. The input impedance of the amplifier Z_A is 22kΩ. nominal

Aerial/Propagation Mismatch

By R. J. HITCHCOCK,* M.A., A.M.I.E.E.

THE success of the first transatlantic submerged repeater cable and the planning of a second emphasises the resurgence of the cable as a serious competitor to radio circuits for long distance point-to-point traffic. This seems an apposite moment therefore to see whether the h.f. point-to-point services as a whole are exploiting their propagation medium, the ionosphere, to the greatest possible extent.

By using the most modest form of equipment and aerial, costing no more than a few pounds, it is possible to communicate at some time of the day with the most distant parts of the earth. While this phenomenon may be exciting and useful to radio amateurs it has had an unfortunate effect on those financially responsible for the development of point-to-point systems. It has resulted in economies in sites and aerials and in attempts to obtain more out of radio services than the often limited engineering facilities warrant. In this respect the cable engineer has been more fortunate, in that his communication link must be completely engineered before one word of traffic can be passed.

WHY POWER IS OFTEN WASTED IN H.F. POINT-TO-POINT COMMUNICATION SYSTEMS

The advent of leased channel and automatic circuit operation have resulted in the demand for higher circuit performances over the radio path. Whilst constant improvements in equipment are partly meeting this demand, much could be achieved by applying our steadily increasing knowledge of propagation to the design of aerial systems.

Early Lack of Propagation Data.—Serious h.f. point-to-point communication within the Commonwealth can be said to have started about 1927 with the completion of the last of the four Franklin beam array services linking the United Kingdom with the Dominions of Australia, Canada, India and South Africa. It is interesting to reflect that at the time these aerial arrays were planned and erected our knowledge of the ionosphere was still in its infancy and in fact the means of scientifically exploring the ionized layers postulated by Heaviside had not yet been established. That the characteristics of these arrays very closely match the mechanics of propagation now known to exist makes the design of the Franklin beam aerial all the more remarkable, and it was indeed unfortunate that owing to their high cost and inflexibility few such aerials were erected.

It was another thirteen years before Appleton and Beynon[1] published their solution to the problem of a ray propagating through a curved layer with a parabolic ionic-density/height relationship. During all this time the number of h.f. communications systems had steadily increased and more often than not the new services were opened on relatively small wide-band aerials at restricted sites. Of necessity these aerials had to be sited and constructed with insufficient scientific knowledge of the propagation characteristics likely to be met with along the route. Thus throughout the formative years of their development, only a very limited amount of ionospheric data was available on which to base the planning of h.f. services.

Modes of Propagation.—Information on modes of propagation, i.e., the exact path whereby h.f. radio signals travel between two points on the earth's surface using the ionosphere as the medium of propagation, is still very limited.

In the past it has been usual for communications engineers to make simple mode models depicting a series of equidistant hops between the ground and a thin mirror-like reflecting layer at some finite height, usually representative of the F_2 layer. Because such simple mode models consider neither the relative influences of the several layers nor take account of the distance a ray may travel within the F layer during refraction, results based on simple mode methods have been very misleading.

After the second world war there was a tendency to assume that our knowledge of h.f. propagation was complete or at least adequate and to move on to the new problems of v.h.f. During the sunspot minimum period 1953-54, however, it became apparent to many users of point-to-point h.f. that predictions of optimum frequency based on simple modes of propagation often failed. In order both to improve these predictions and to achieve a sounder basis for the design of aerial systems it became evident that far more information on modes of propagation was needed.

During the last three years considerable work has been done on this subject at the Radio Research Station of the Department of Scientific and Industrial Research. In addition to pulse tests on fixed frequency stations as far apart as Osaka (Japan) and Ascension Island, a transportable equipment capable of variable frequency operation is now in use[2]. It is not the purpose of this paper to discuss the methods whereby the active modes of propagation along any great-circle path can be deduced from observations of pulse transmissions except to note that the main measurements consist of (a) observing the angle of elevation of the down-coming rays as described by Wilkins and Minnis[3], and (b) observing the break-up and relative arrival times of the various components of the original pulse. In addition further valuable information on modes of propagation is being

* Cable and Wireless Ltd.

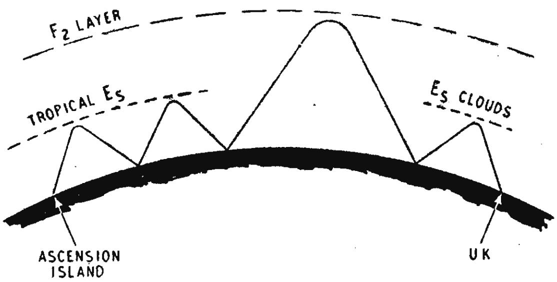


Fig. 1. Typical propagation mode between Ascension Island and the United Kingdom. The diagram is not to scale and the arrival angle is actually 6° to the ground.

obtained from the back-scatter observations described by Shearman.[4] Although only a small part of the Radio Research Station's observations and conclusions have yet been published[2], the complexity of aligning possible propagation modes to the observed results is an exceedingly difficult task. On the Ascension Island/U.K. path where nearly 5000 observations have so far been made it is apparent that during daylight the first two or three hops from Ascension are between the earth and the tropical sporadic E layer, the remaining hop or hops being via the F_2 and or temperate E_s clouds[5] (Fig. 1). The most interesting feature of these tests is the confirmation that the predominant modes arrive at very low angles of elevation, in fact the arrival of two main modes below 7° was a normal occurrence.

Advantages of Using Low-angle Modes.—The correct exploitation of these low-angle modes results in two very definite advantages to the user of h.f. In the first place the least attenuated mode is the one arriving at the lowest angle, that is to say the mode suffering the fewest number of ground and ionosphere reflections.

Calculations of the attenuation suffered by different modes is naturally complex and will vary with circuit, frequency, time, season, type of ground at earth reflection point, etc. On a medium distance north-south multi-hop circuit of the order of 7000 km, for example, where the ground reflection points are over land and only propagation via the F_2 layer is considered, the total attenuation of the lowest ray during the daytime is likely to be some 6–8 dB less than that for the next highest ray. During the night this gain will probably be reduced to the order of 4–6 dB. To this may be added the relative gains due to focusing caused by layer curvature (usually called convergence gains). This focusing effect is greatest for near tangential rays and therefore the highest gains occur on the lowest angle modes. Taking into account theoretical values[6] of convergence gains for the same sort of circuit, and *assuming that the gains of both transmitting and receiving aerials are constant throughout the vertical plane*, then the field strength of the mode with the lowest angle of arrival might be expected to be some 9–11 dB above that for the second highest arrival angle.

The second great advantage to be gained from exploiting the lowest angle mode is that this mode will be present for the longest possible time; in fact near the fade-in and fade-out periods it will be the only mode to propagate. Kift[5] has shown that the operating time gained can be very considerable. On the Ascension Island/U.K. circuit in April 1956, for example, the lowest mode (4°) at 20 Mc/s would be present from about 0700 to 2000 G.M.T. whereas a higher angle mode at 12° would only be present from about 0930 to 1900 G.M.T.

It has been shown that the lowest angle mode has both the greatest potential field strength and the longest operating time. That full advantage of this has seldom been taken in the past is probably due to two reasons which may well be interconnected. In the first place there has unfortunately existed a belief that angles of arrival were considerably higher by night than by day, this seems to have been coupled with the generalization that low frequencies necessarily meant high angles, day or night. Of course in certain circumstances low frequencies are necessarily associated with high angles but as a generalization there is no validity for the belief. Appleton and Beynon[1] have shown that for a thick parabolic layer at a given height and thickness, provided the angle of incidence of the ray with the layer remains constant, the distance the ray penetrates through the ionosphere depends on the ratio f/f_0 where f is the transmitted frequency and f_0 the critical frequency at the area of refraction. In practice, over much of the route, the ratio f/f_0 is often higher by night than by day resulting in greater hop lengths by night. *Quite often, therefore, on multi-hop circuits the main angle of arrival will be lower by night than by day.* (Of course hop lengths will in any case be slightly different by night as layer heights either increase or decrease, depending on geographical location.)

The second reason why low-angle modes have seldom been exploited is to be seen in the inherent nature of aerials themselves. For example, if on a certain circuit, where the day frequency is 19 Mc/s and the night frequency 8 Mc/s, low-angle modes arrive at about 7° both night and day; then for simple horizontal dipoles to have their major lobes at this angle, the one for 19 M/cs would need to be 120ft above ground and that for 8 Mc/s 280ft above ground. Masts for such aerials are not often available. This discrimination by horizontally polarized aerials against low-angle modes at low radio frequencies (Fig. 2) may well have significantly contributed to the belief that at night only high-angle radiation existed.

" Avoidable Aerial/Propagation Matching Loss "—If it is assumed that the angles of arrival and departure are equal then it is obvious that on an h.f. circuit optimum performance on any given frequency is achieved when the major lobes in the vertical plane of any given transmitting and receiving aerials both coincide with the lowest active mode of propagation. If we define this state of affairs as entailing no " avoidable aerial/propagation matching loss " then it is interesting to see the magnitude of the loss suffered by typical point-to-point systems in use to-day.

Consider a middle-distance route of the order of say 7000 km where both the transmitting and receiving aerials are medium-sized rhombics limited in size to about 350ft side length and in height to about 100ft. (This can be considered typical of many of the better international and inter-Commonwealth stations.) The frequencies used on such a route will probably vary from 7 to 20 Mc/s and for the purposes of this example predominant modes of the orders of 4° and 12° have been taken as representative of those met with in practice. If both aerials are at the top of their respective masts then the following approximate "avoidable aerial/propagation matching losses" can be expected to occur on these high and low angle modes as the various frequencies are used:

Main Mode Arrival Angles	*Order of Frequency.* 20 *Mc/s*	15 *Mc/s*	10 *Mc/s*	7 *Mc/s*
4°	−2 dB	−4 dB	−12 dB	−17 dB
12°	−15 dB	−11 dB	−10 dB	−11 dB

If the aerial height was limited to 70ft, a limitation still met with in practice, then for the same angle of elevation, path lengths, etc., the approximate "avoidable aerial/propagation matching losses" might be expected to be:

Main Mode Arrival Angles	*Order of Frequency.* 20 *Mc/s*	15 *Mc/s*	10 *Mc/s*	7 *Mc/s*
4°	−4 dB	−5 dB	−14 dB	−20 dB
12°	−12 dB	−11 dB	−12 dB	−15 dB

The above figures are computed from the relative gains of the theoretical polar diagrams of both transmitting and receiving aerials at the required angle of elevation and operating frequency as well as average values of different mode attenuation and convergence gains. When it is also considered that the lowest mode is always present and will normally exist for considerably more of the time than the higher modes, particularly near the fade-in and fade-out times, then the degree to which many of the present h.f. systems fail to make use of their propagation medium is evident.

Reducing the Losses.—If the 15-, 10- and 7-Mc/s transmissions in the above example were made from transmitting and receiving aerials of the same size but at 150ft above ground then the approximate "avoidable aerial/propagation matching losses" might be expected to reduce to the order of:

Main Mode Arrival Angles	*Order of Frequency.* 15 *Mc/s*	10 *Mc/s*	7 *Mc/s*
4°	−2 dB	−3 dB	−4 dB
12°	−14 dB	−10 dB	−9 dB

Thus without enlarging the aerials it should be possible, by increasing the height from 100ft to 150ft, to increase both the operating time and circuit gain. It will be seen that this latter figure theoretically varies from about 2 dB at 15 Mc/s to 7 dB at 10 Mc/s, with the gain at 10 Mc/s increasing to 9 dB during periods when only the lowest mode is propagating. Further overall circuit gains could be achieved by increasing the size of the rhombics, but unfortunately site limitations often make this impossible in practice. (It is estimated that if the transmitting and receiving aerials in the foregoing example were increased to 550ft side length, against the 350ft side length considered, a further circuit gain of the order of 5 to 6 dB could be achieved at 10 Mc/s.)

Characteristics of large and high rhombic aerials at the new Rugby "B" station of the British Post Office have been discussed by Booth and MacLarty[7] and Cook and Hall[8]. It must remain questionable, however, whether it is a wise concept to consider non-resonant aerials such as the rhombic capable of producing suitable radiation characteristics over a wide range of frequencies, say of the order of one octave. The angle of elevation of the main lobe will vary considerably over this range and consequently discriminate against the low angle modes for much of the time. To reduce these losses to a minimum it is considered that an aerial should only be used over a relatively narrow band of frequencies and that the average 24-hour radio circuit requires four designs of aerial to cover the sunspot maximum and sunspot minimum day and night frequency ranges. It has been found that by this means it is usually possible to restrict the design of any one aerial to the approximate frequency range 1 to 1.4. Of course, only two of the four designs need be erected at one time.

Conclusions.—Many point-to-point h.f. circuits in operation to-day are unnecessarily inefficient because aerial designs are not matched to the predominant modes of propagation. Although our knowledge of modes is still very limited it is steadily growing and in the near future methods are likely to be evolved whereby mode prediction will be practicable. In the meantime current research indicates that on medium and long distance circuits the low angles of arrival predominate over all other angles both by day and night and the exploitation of these low angle modes, by increasing aerial heights, would result both in increased operating hours and increased circuit gains. In addition many

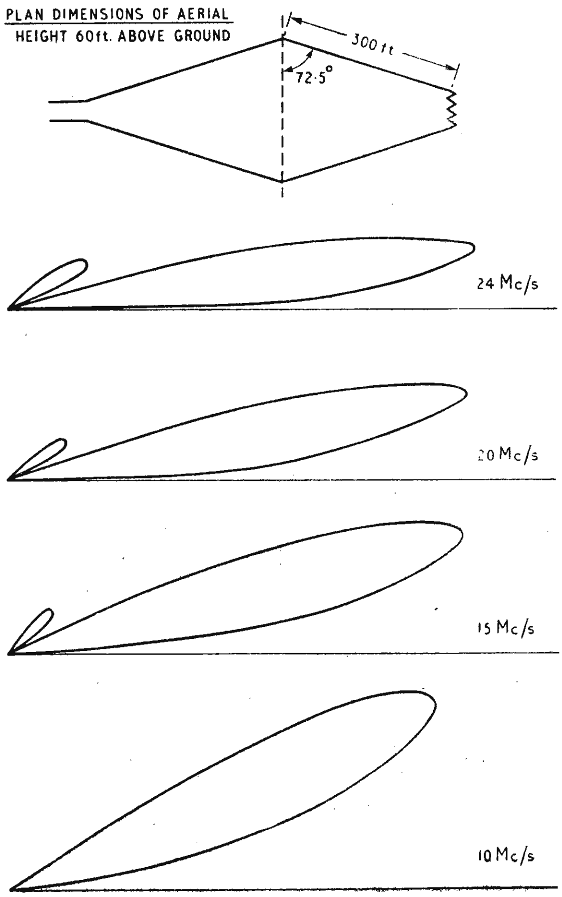


Fig. 2. Variations in angle of elevation of major lobe of a typical rhombic aerial with changes in frequency.

h.f. services are trying to operate from inadequate sites where space is insufficient to allow the construction of larger, higher-gain aerials.

The overall gains to be achieved from improvements to aerials and sites are considerable. It is estimated that on many existing point-to-point services gains of from 10 to 15 dB are possible on the lower frequencies. This could be of considerable importance during sunspot minimum years when operating frequencies are of necessity low and circuit performance often poor.

Further, in order that the "avoidable aerial/propagation matching loss" should be kept to a minimum it is considered that non-resonant aerials such as the rhombic, which are generally considered to have a wide frequency range of the order of 2 : 1, should normally be confined to much narrower frequency limits.

ACKNOWLEDGEMENT.—The author would like to acknowledge most helpful discussions with Mr. F. Kift.

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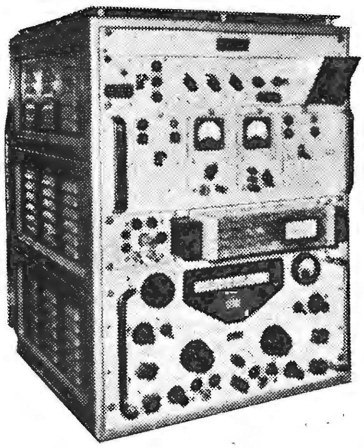
Radio Teleprinter Equipment

THE unconventional Type RA17 communications receiver, described in the August 1957 *Wireless World*, forms the heart of a new frequency shift keying (FSK) radio teleprinter receiving equipment introduced by Racal Engineering. Known as Type RA62 this FSK receiving terminal, as it is called, comprises, in addition to the RA17, the Frequency Shift Converter Type FSW1, Cathode Ray Monitor Type CRM1 and, as an optional unit, Regenerative Repeater Type TRR2. All four are shown in the illustration housed in a cabinet measuring 30in high, 21in wide and 30in deep, and weighing 213 lb. Provision is made for operation on a.c. supplies of 50 to 60 c/s at 100 to 125 or 200 to 250 volts.

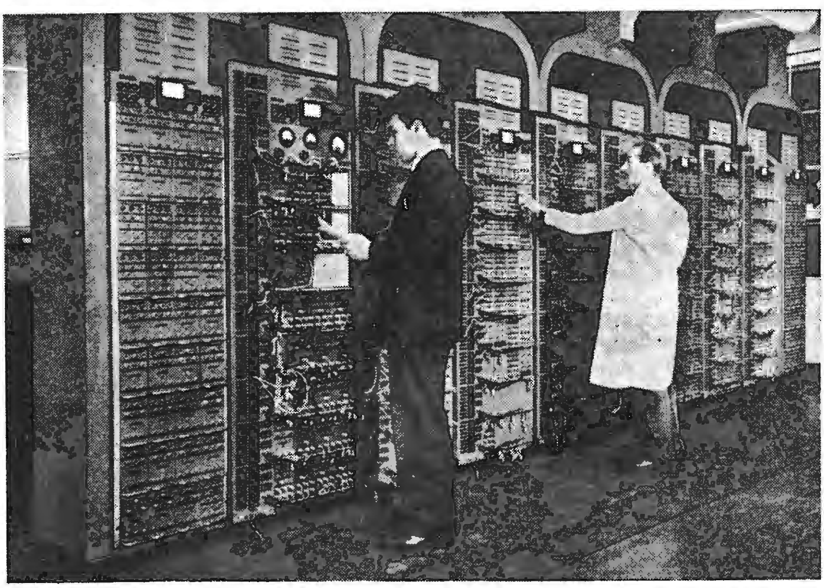


The audio output from the receiver, which is on 600 c/s or 2,550 c/s according to the deviation used, is amplified and shaped in the FSWI unit and emerges as d.c. mark and space pulses of suitable amplitude for direct operation of a teleprinter, or tape perforator.

The CRM1 unit is a compact oscilloscope designed specifically for monitoring the audio output of the receiver, and it serves also as an aid to tuning.

The function of the TRR2 regenerative repeater is to generate distortionless telegraph signals from input signals which may carry heavy and variable distortion and, which, without correction, are likely to impair the satisfactory working of a teleprinter. It is also particularly useful in relay circuits where the received signals are re-transmitted.

The makers are Racal Engineering, Ltd., Western Road, Bracknell, Berks.



CONTROL SYSTEM SIMULATOR using purely electronic techniques has been designed and built by E.M.I. Electronics. Known as GATAC, it is actually an analogue computer and is intended primarily for studying the complex non-linear three-dimensional control problems associated with guided weapons. It is said to be capable of simulating the control, guidance and propulsion systems and the aerodynamic performance of any existing British guided weapon. Recent work has been on the Naval guided weapon SEA SLUG. The computer also has general application to the study of industrial control systems such as in chemical and nuclear engineering.

"Grid-Diode" Saw-Tooth Generator

By T. A. MENDES, M.B.E.

A SIMPLE TIME-BASE CIRCUIT WITH A WIDE FREQUENCY RANGE

THE saw-tooth generator to be described was developed by the writer in the course of building a general-purpose oscilloscope, and has been in use for some time now, giving excellent results. To the best of his knowledge and belief it is new. Using common types of valves, it is almost ridiculously simple to set up, and provides a constant-voltage output that is independent of frequency, together with voltage and current pulses suitable for flyback black-out application. Its frequency range extends certainly to 250 kc/s and probably higher; it synchronizes readily; the valve heaters may be run from an existing earthy supply.

The output voltage is too low for direct application to the deflector plates of a c.r.t., a fact that some may consider a major disadvantage. But is it? A circuit that develops a voltage high enough for such direct application has disadvantages of its own: at least one extra valve, and sometimes two, are required to achieve reasonable linearity; the voltage applied to the c.r.t. is asymmetric, leading to trapezium distortion and deflection defocusing; the amplitude control varies the sweep frequency as well as the width of the trace. There is gnashing of teeth when the time base is not in use (as for phase-shift tests, etc.), and no X-amplifier is forthcoming.

In the low-voltage circuit there is no difficulty about linearity if the charging source is high enough, and the valves saved from "linearity duty" can be applied as an amplifier (preferably push-pull), thus clearing up all the difficulties listed above. The circuit to be described is therefore of considerable practical as well as academic interest.

As is usual, the saw-tooth voltage is produced by charging a capacitor slowly through a high resistance, then discharging it rapidly through a low resistance. As, however, part of the discharge path is the diode formed by the grid and cathode of a triode, it may be as well, before proceeding to the actual circuit, to recapitulate some of the peculiarities of triodes in the positive-grid region.

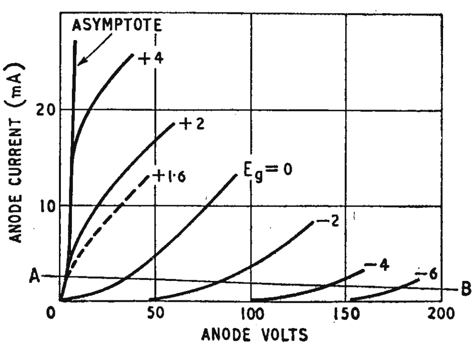


Fig. 1 Anode-volts anode-current curves of typical small triode (½ 6J6) showing positive-grid characteristics, with 150KΩ load-line drawn from 350V.

Consider, then, Fig. 1, which is the anode-volts/anode-current curves of a typical small triode—one section of a 6J6. Any triode will be represented by a similarly shaped and grouped "family," only the scales varying from type to type. It will be seen that in the positive-grid area all the curves run together into one curve, which may be termed the asymptote. (This statement is not mathematically true, but is amply true for all practical purposes.)

"Freezing" the Working Point

The line AB in Fig. 1 is a 150 kΩ load-line drawn from an h.t. supply voltage of 350 V, and will be seen to cut the asymptote at the point where the "E_g = 1.6 V" curve (shown dashed) just enters it. If, therefore, the valve represented by the curves were connected in series with 150 kΩ across a 350 V supply, and the grid voltage gradually changed from some negative value into the positive area, the working point would move along the line AB towards the left—but only as far as the asymptote. Any increase in positive grid voltage beyond +1.6 V would merely leave the working point "frozen" on the asymptote. The anode voltage and current would remain unchanged for all values of E_g greater than +1.6 V. The grid voltage at which this "freezing" takes place will be referred to in what follows as the "freezing bias" and be denoted by E_f.

A further point of importance is that when the grid is positive it draws current from the bias source, and thus appears as a finite resistance. The value of this "diode" resistance—which we shall denote by r_d—may be obtained either from the valve curves if available or by experiment. It is not constant, but may be considered so for what follows. In general it is of the order of 200 or 300 ohms, a figure that in the writer's experience is suitable as a first approximation for any small triode.

We may now turn to the actual circuit, which is shown in Fig. 2. Here V1 is a small medium- or high-mu triode (½ 6J6) with the characteristics sketched in Fig. 1. V2 is a small beam tetrode (6AQ5). R_c biases V2 to the required anode current. R_g is of course merely a grid leak. The remaining components will be discussed later.

A brief outline of the operation of the circuit, shorn of all details, would run as follows: With capacitor C uncharged or only slightly charged, the cathode current I_k of V2 sets up across R_k a voltage E_k more than sufficient to cut off V1. C, however, charges slowly through R and a point is reached when the grid of V1 is carried sufficiently positive to approach the cathode voltage and allow

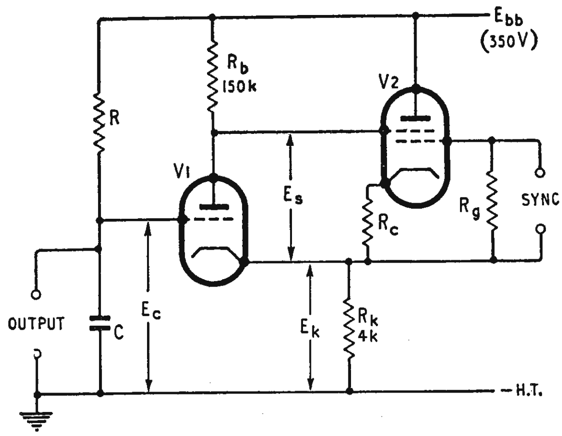


Fig. 2 Basic circuit of the "grid-diode" saw-tooth generator.

V1 to conduct. The plate current of V1 reduces E_s which in turn reduces I_k and consequently also E_k, carrying the cathode of V1 negative and further increasing its anode current. The action is cumulative, and E_s abruptly drops to so low a value that V2 is effectively cut off, while the grid of V1 is suddenly left positive to its cathode by a voltage *greater than the "freezing bias."* C now discharges through R_k via the diode formed by the grid and cathode of V1, and the grid voltage drops. E_s does not at first change, as the working point is frozen on the asymptote. Eventually, however, the grid-cathode voltage drops to the value of the " freezing bias " and tends below, so that E_s can begin to rise, thereby triggering off the reverse cumulative action, abruptly restoring the original voltage across R_k. V1 is once more cut off; C recharges slowly through R, and the cycle repeats.

Due to the d.c. coupling between the two valves the cumulative actions described are extremely fast, and may, to a very close approximation, be considered instantaneous.

With the foregoing brief outline in mind we can now make a more detailed examination of the processes involved, and develop design formulae.

If E_k and E_s are considered to represent the numerical values of these voltages at a time at which V1 is cut off, and if we write E_o for the cut-off bias of V1 at an anode voltage of E_s, then clearly V1 will start conducting only when C has charged to a voltage:

$$E_c = E_k - E_o \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \text{(i)}$$

at which point V2 is suddenly cut off. With V2 cut off, the current in R_k is the sum of the grid current (I_g) of V1 which is supplied by the capacitor C, and the anode current (I_b) of V1 which is supplied by the h.t. line.

The voltage across R_k is now given by $R_kI_g+R_kI_b$, and since I_b is the " freezing bias " anode current of V1, and is thus known and constant, we may put $R_kI_b = E_x$ and it is clear that the source of I_g sees the common cathode resistor as a resistance R_k in series with a resistance-less generator developing a voltage E_x so polarized as to oppose it. Also in series is of course the diode resistance r_d of the grid-cathode path. Thus an effective voltage of $E_c - E_x$ is driving a current I_g through a load of $r_d + R_k$. The grid-to-cathode voltage is that across r_d and is given by:

$$E_g = (E_c - E_x)\frac{r_d}{r_d + R_k} \quad \ldots \quad \ldots \quad \text{(ii)}$$

and for the circuit to work it is necessary for the value of E_g found from equation (ii) to be greater than the " freezing bias " E_f found from the curves for V1.

Now C discharges and E_c drops (while E_x remains constant) until the point at which the value of E_g given by equation (ii) equals that of E_f. The voltage across the capacitor at this stage we shall denote by E_c' and is found by substituting E_f for E_g in equation (ii) and solving for E_c. This works out to:

$$E_c' = nE_f + E_x \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \text{(iii)}$$

where $n=(r_d+R_k)/r_d$, and at this point V1 is once more cut off and the cycle repeats. Apart from the initial long charge from zero to E_c then, the saw-tooth voltage across C consists of a slow rise from E_c' to E_c followed by a rapid drop back to E_c'. Thus the peak-to-peak sweep voltage developed is given by:

$$\triangle E_c = E_c - E_c' = E_k - (E_o + nE_f + E_x) \ldots \quad \text{(iv)}$$

The ratio of scan time (t_s) to flyback time (t_o) is of course a function of the ratio R to R_k+r_d, and obviously R_k is best held as low as possible. In practice R will generally be in two parts—one variable and one mixed. By proper choice of the value of the fixed resistor the time ratio can be held to a predetermined minimum—say 10:1. For those who may be interested, the time-ratio is given by:

$$\frac{t_s}{t_o} = \frac{R}{R_k + r_d} \cdot \frac{\log A}{\log B} \quad \ldots \quad \ldots \quad \ldots \quad \text{(v)}$$

where:

$$A = \frac{E_{bb} - E_c' - \triangle E_c}{E_{bb} - E_c'}$$

and

$$B = \frac{E_c' - E_x}{E_c - E_x}$$

As a numerical example consider the circuit of

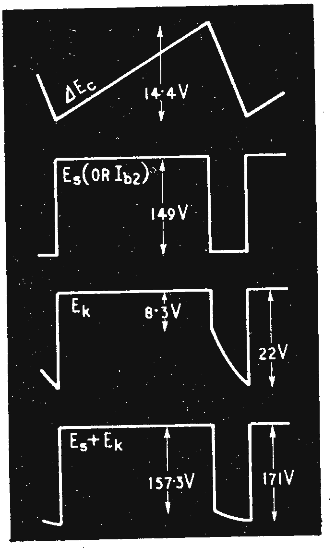


Fig. 3 Waveforms in the circuit. Voltages are for the numerical example discussed in the text. The flyback is shown disproportionately wide for clarity. Although "idealized", the curves drawn differ only very slightly from corresponding oscilloscope traces at frequencies at which stray capacitance is not troublesome.

Fig. 2 with R_c so chosen that the cathode current of V2 with V1 cut off runs to 16mA. This produces a voltage E_k of 64V. Let also $E_s = 150V$ when V1 is cut off. Reference to Fig. 1 shows that at an anode voltage of 150V V1 cuts off at $-6V$. This gives us $E_o = 6V$. Also from Fig. 1 we find $E_f = 1.6V$, and at this grid voltage E_s will be about 1V (quite low enough to cut off V2) while the anode current I_b is around 2.25mA. We may call this 2.5mA to account for the very small cathode current in V2, and this gives us $E_x = R_k I_b = 10V$. Since we have already found that r_d is approximately 200 ohms, our value for n works out to 21. These values inserted in equation (iv) yield a sweep voltage $\triangle E_c = 14.4V$, which should be sufficient to drive any amplifier.

Note here that to find E_f the load-line must be drawn from the full h.t. supply voltage E_{bb}, and not from E_s, since by the time the asymptote is reached V2 is cut off and may as well not exist.

Circuit Waveforms

At this point we may give some thought to the other waveforms in the circuit, and a moment's consideration will show that E_s and E_k as well as the anode current I_{b2} of V2 are in the form of negative-going pulses, the shapes of which are sketched in Fig. 3 along with the saw-tooth to indicate time-relationships. The curve at the trough of E_k is caused by the discharge current of C. The most easily available pulse is that between the anode of V1 and earth, and is the sum of E_s and E_k it is of a value and polarity ideal for flyback black-out (return-trace blanking).

Actually the circuit could be used purely as a pulse generator, producing either current or voltage pulses, the current pulses existing in the anode circuit of V2. The current pulse may with advantage be used to obtain a voltage pulse by inserting a low resistance in the anode circuit of V2. Since such a resistance would in general be very much smaller than R_b for an equivalent voltage, stray capacitance would be so much less troublesome at high frequencies.

Synchronization is straightforward, the mechanism being obvious from Fig. 2. However, input across R_g will not ordinarily be convenient, and the more normal method will be the application of the sync signal between the grid of V2 and earth. Unfortunately V2 then becomes a cathode-follower, and it would appear that a relatively large signal might be necessary.

However, while no quantitative investigation has been made, the circuit has been found to be quite sensitive to sync signals of the order of one volt or so, even with the input between grid and earth. The actual circuit used by the writer is shown in Fig. 4 and is extremely sensitive to synchronization. The d.c. coupling of the sync valve (V3) does away with the need for R_c and R_g of Fig. 2. The operating anode voltage of V3 must of course be less than E_k, but is quite sufficient if E_k is of the order of 40V or more.

What may be annoying in certain applications, is the transfer of the pulses across R_k into the source of sync signal via the grid-cathode capacitance of V2 (and the anode-grid capacitance of V3): but this can be rendered negligible by operating V3 as a pentode, taking advantage of its very small C_{ga}.

Linearity is excellent, since C need never charge to more than 5% or so of the applied voltage, which in this case is $(E_{bb} - E_c')$. Since linearity is acceptable up to 15% charge, a lower source voltage could be used to enable smaller values of C to be employed for the same frequencies, or lower frequencies to be obtained with the same value capacitors. If such a low voltage source is obtained by dropping the h.t. supply, however, a voltage regulator valve is likely to be necessary. In any case, purists may apply any trick "linear" circuits they desire (pentodes, cathode-followers, etc.).

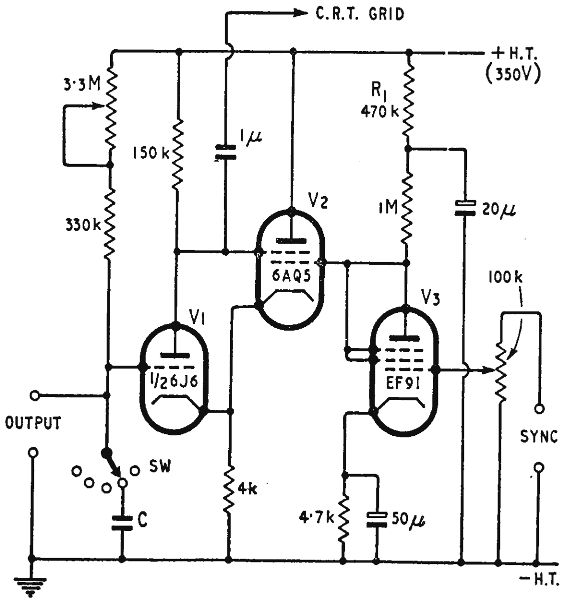


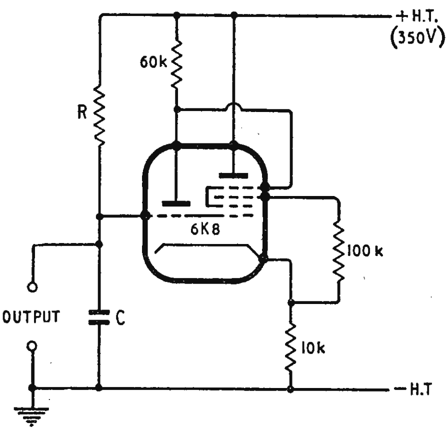
Fig. 4 Complete circuit as used by the writer, showing the (optional) sync amplifier valve, V3. The switch SW selects different capacitors for "coarse" frequency control, while "fine" control is provided by the 3-MΩ potentiometer.

As to amplitude, a glance at equation (iv) will show that $\triangle E_c$ is entirely independent of R and C, and hence of the repetition frequency. This is quite true in practice: the trace on the oscilloscope screen is constant whatever the setting of the "coarse" (C) or "fine" (R) frequency controls. While for long-term accuracy of calibration this may be not any too reliable, because of valve deterioration—especially since grid current flows—for short-term approximate work the constancy of output is a definite advantage.

No amplitude control has been provided in the circuit itself, since it is intended to work into an amplifier with a gain control. Any control that varies $\triangle E_c$ will necessarily vary the frequency as well—an annoying effect inherent in any amplitude contro that directly varies the generated voltage. However, if an amplitude control is particularly desired, equation (iv) provides the clue: vary E_k. This is easily done by making R_c of Fig. 2 or R_1 of Fig. 4 variable, and indeed such an arrangement could be quite handy if fitted as a pre-set control

: initial adjustment and occasional correction of libration as valves age.

So much for the two-valve version actually used the writer; it will be appreciated that the circuit easily adaptable to use with the triode-pentode lves now so popular as mixers in v.h.f. sets. Such lves were not available to the author when this :icle was written but he did try—with tongue in eek—the circuit of Fig. 5. Somewhat to his surise, it worked extremely well, producing a



ïg. 5 *This experimental version, using the once-popular American triode-hexode converter valve 6K8, produced an excellent saw-tooth of about 8V. Triode-pentodes such as ıX8, 6U8, etc., would probably be better.*

v-tooth every bit as good as that of the two-valve :sion, though E_s and E_k curves were humped and ınded, and unsuitable for flyback black-out use. ıis was probably due to the extension of the grid of /1 " into the cathode-to-anode stream of " V2," effect that would be absent in the new triode-ıtodes.

Many popular makes of oscilloscope still appear be using the thyratron (gas-discharge) sweep ıerator followed by an X-amplifier, obtaining back black-out by differentiating the signal from : positive-going X-plate through a low time-ıstant coupling to the " grid " of the c.r.t. The cuit of Fig. 5 (or its triode-pentode version) very strongly recommended as a replacement en the thyratron finally " goes," as its wider quency range, its constant amplitude, and its :apness make it well worth the small trouble of ıdifying.

Those who are interested, but have qualms ɔut the complications of designing an amplifier, y rest assured. A single EF91 or Z77 operated m a 300-V supply with 250V on the screen and 1.5V s will provide a practically distortionless output 200V peak-to-peak across a 10,000-ohm anode d resistor for an input of 1.06V r.m.s. (3V pk-pk). is is ample for an average 5in c.r.t. as an X-plifier. Assuming a total stray capacitance of 50pF frequency response will be 3dB down at 320kc/s B down at 160kc/s). A shunt-peaking 2.5mH ıke in series with the anode resistor will improve ; to 1dB down at 430kc/s (3 dB down at 580kc/s)—ple for a general-purpose oscilloscope. A pair of 91s under the same conditions in cathode-ıpled push-pull would provide the same *gain* and a balanced output of 400V peak-to-peak. The amplifier is simple enough.

Finally, a few design considerations. The starting point will generally be the output voltage requirement, based on the input demands of the amplifier. It is as well to develop a voltage considerably in excess of the maximum input to the amplifier, if only to enable the trace to be " spread out." (The amplifier will distort, of course, but the distorted part of the trace will be off the screen.) Also it is desirable to keep the saw-tooth between 5% and 10% of the charging voltage in order to keep the value of C within bounds at low sweep frequencies.

Since it is desirable to keep R_k as low as possible, a low value of E_k is indicated, and hence low values for all terms within brackets in equation (iv). Thus a short-base, high-slope valve should be selected for V1 to keep E_o down, and the valve chosen should also have its asymptote as close to the zero volts ordinate as possible in order to ensure a low value for E_s during discharge. E_f and E_x depend on the value of R_b, which should be as high as possible, and here enters V2.

For V2 a valve with low screen current requirements is indicated, so that R_b can be kept high without too far reducing screen voltage. Beam tetrodes seem preferable to pentodes in this respect. Since a low value for R_k is in any case being aimed at, this takes care of *n*.

With the value of R_k tentatively decided, that of E_k is found, and the anode current of V2 derived. A little juggling with R_k and I_{b2} may be necessary to complete the job.

An alternative design method is that of throwing together a few reasonably assorted components and poking about till the desired output is attained; the circuit is a sufficiently persistent—not to say insistent—oscillator to permit of this approach. Had it not been the chances are that the writer, at any rate, would never have discovered it.

R.I.C. Specifications for Radio Materials

CARE is necessary when choosing metallic finishes for metal parts used in radio and other electronic equipment, as some combinations of plating and base metals can greatly accelerate corrosion under tropical conditions.

Contact potential must also be considered and a guide to the combinations found satisfactory in practice is given in the revised specification (Issue No. 2) of RIC/1000/B now being issued by the Radio Industry Council. The subject is choice of finishes in common use for metals; also for wood and insulating materials, including conducting coatings on glass and ceramic.

Concurrently available is RIC/1000/A giving guidance on the choice of materials for use in radio and other electronic equipment. Classes of materials dealt with include metals, plastics, insulating materials, wood, lubricants, wires, adhesives and soldering fluxes and elastomers. Grouped under the last-mentioned heading are natural and synthetic rubber, polythene, PVC and similar materials. Electrical and mechanical tests are described.

These specifications are not mandatory, but a British Standard based on them is at present under consideration by the British Standards Institution.

Copies of these two specifications can be obtained from the Radio Industry Council, 59, Russell Square, London, W.C.1; RIC/1000/A costs 10s and RIC/1000/B 8s, including postage.

The "Quad" Aerial

Its Advantages for Indoor Use on Bands I and II

By F. B. SINGLETON (GW3CGM)

SOME ten years ago, when ten-metre amateur activity was at a peak occasioned by the solar cycle, the "quad" aerial was widely used. The reason for this account is that the writer feels it ought to be more widely known, particularly as it has advantages when used as an indoor aerial.

The "quad" is believed to have originated at Station HCJB, Ecuador, and, when it first appeared on the ten-metre scene, usually consisted of a two-turn square loop, with a quarter-wavelength side, and backed by a similarly constructed reflector, the planes of the two loops being parallel. The loops were mounted so that the sides were all at 45 degrees to the horizontal, and, for horizontal polarization, were open at the bottom corner for connection of a 300-ohm feed line to the driven loop and a phasing stub to the reflector. An investigation at the time[1] showed that folding the driven loop did not result in a very close match to the line impedance and pointed out that folding the reflector was no more necessary than with any other type of aerial. It also showed that when the diagonals of the loop were all at 45 degrees to the horizontal the gain was slightly higher, as expected on theoretical grounds.

With the fading of sun-spot activity the "quad" was lost to view for a time, but about two years ago it made a reappearance as a twenty-metre aerial and it was stated that the impedance of a single-turn loop with reflector spaced 0.2 wavelength was approximately 75 ohms and the gain claimed for the two-element combination was 10 dB, although 8 dB seemed a more reasonable figure[2].

Modern houses have roofs which are less steeply pitched than formerly, with insufficient height for a full-size Band I aerial and insufficient spread, except when parallel, or nearly so, to the ridge,

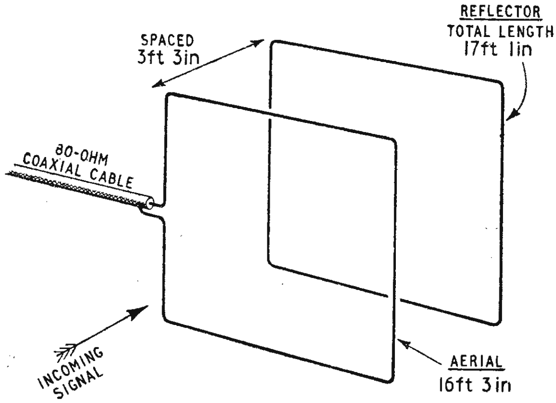


Fig. 1. Dimensions of "quad" aerial for Channel 4 (60 Mc/s).

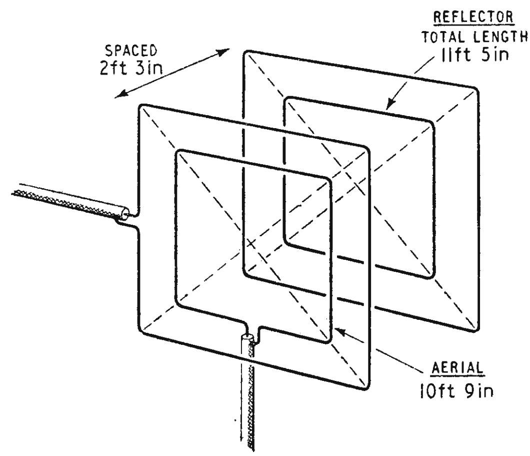


Fig. 2. Addition of an inner loop for Band II sound transmissions.

for a slot aerial. The "quad," which is both shorter than a dipole and narrower than a slot, would appear to be the answer to the inside aerial problem for the inhabitants of such houses, especially in view of the gain claimed for it. It is now two years since the writer brought one into use on Channel 4 (Sutton Coldfield), with satisfactory results. Fig. 1 gives a sketch of the one then in use. It will be seen that there is no phasing stub connected to the reflector, the necessary reactance being introduced by the more usual method of making the reflector about 5% longer than the driven element.

With the coming of Band II sound broadcasting the need for a more effective aerial than a piece of wire strung along a picture-rail was felt, and in the meantime further descriptions had appeared[3, 4] which showed that it was possible to combine "quads" for different bands. As a result, the system shown in Fig. 2 was set up and is working satisfactorily.

It will be seen that the Band I loop is opened in the centre of a vertical side (for vertical polarization), which side being a matter of convenience, and the Band II loop is opened in the centre of a horizontal side for the connection of the feeders. The spacing is a compromise for the two frequencies, since reducing it has the effect of lowering both gain and impedance. As originally described, the total length of one loop was based on the formula $468/f$ for a half-wavelength, where f is the frequency, but this formula is intended to allow for end-effects on a half-wave dipole. As the "quad" has no ends the writer thought it would be better to use $492/f$ for calculating the wire length,* and

* Note, actual length of wire = $2 \times 492/f$—Ed.

although no measurements have been possible it does appear to give results which are certainly no worse than those obtained with shorter elements.

There would appear to be no great compromise involved in combining "quads" for Channels 3, 4, or 5, of either vertical or horizontal polarization, with a Band II system, but the combination with Channels 1 or 2, particularly the former, gives a gross mis-match on one or other band. The writer is not in a position to investigate this, but suggests that the spacing be set for the Band I signal and the results obtained on Band II be accepted. It appears that adequate signal on Band II is obtained in most locations where a usable Band I signal, from the same transmitting site, is present, and when the Band II aerial is a simple dipole. That being the case, it seems that a single Band II loop, with an impedance of the order of 110 ohms and a gain over the dipole of about 1 dB, should be more than adequate. In the event of the transmitters not being co-sited the problem is merely that of siting two systems in the roof rather than one.

The dimensions given are for a frequency of 60 Mc/s, for the Channel 4 "quad" and for 90 Mc/s for the Band II system. For other frequencies the dimensions should be scaled accordingly.

Construction is quite simple using plastic-covered stranded wire carried on frames made of two garden canes forming the diagonals of the square. Pieces of string passed through holes in the canes outside the corner of the squares support the wire and make adjustment of the positions of the corners easy. Metallic supports of any description might well result in shorter loops being necessary because of the increased capacitance effects.

It only remains to say that the writer's "quad" is slightly more than 60 miles from the transmitting aerial at Sutton Coldfield.

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[1] "Technical Topics—The 'Quad' Antenna," *QST*, Nov., 1948

[2] S. B. Leslie, Jr., "A Cubical Quad for 20 Metres," *QST*, Jan., 1955.

[3] Albert M. Magagna, "A Dual Quad for 15 and 10," *QST*, May, 1956.

[4] John C. Pomeroy, "A Tri-Band Quad," *QST*, Sep., 1956.

Books Received

Dry-Battery Receivers with Miniature Valves by E. Rodenhuis. Volume in the Philips Technical Library series discusses data on and uses of various types of miniature valves and includes detailed description and circuits of six complete a.m. and two a.m./f.m. receivers. Pp. 242; Figs. 248. Price 32s 6d. Cleaver-Hume Press, Ltd., 31, Wright's Lane, London, W.8.

Department of Scientific and Industrial Research Report for the year 1955-56, includes a summary of work carried out by the various research establishments of the department, and co-operative industrial research organizations. Pp. 314; Price 9s 6d. H.M.S.O., London.

Transistor Circuits by Rufus P. Turner, covers d.c., a.f., r.f. and i.f. amplifiers, oscillators, use in power supplies, triggers and switches, control devices and also complete radio receivers and test instruments including Geiger counters. Pp. 160; Figs. 147. Price 2.75 dollars. Gernsback Library Inc., New York, 11. Available in this country from Modern Book Co., 19-23, Praed Street, London, W.2. Price 22s.

Simplified Electronics by Rufus P. Turner. General introductory book covers most aspects of the subject including semi-conductors and microwaves. Pp. 126, many illustrations and figures, price 75 cents. Trend Books, 5959, Hollywood Blvd., Los Angeles 28, California. Available in this country from Arthur F. Bird, 66, Chandos Place, London, W.C.2, Price 7s.

A Stable Decade Amplifier for the Frequency Range 10 c/s to 1 Mc/s by D. C. G. Smith, B.Sc., A.Inst.P. Describes design and performance of such an amplifier with a gain stabilized to 10 ± 0.1. Pp. 10; Figs. 7.

Radio Interference from High Voltage Distribution Systems by S. F. Pearce describes measurements on existing 33 and 132 kV lines. Pp. 7; Figs. 11.
The above two reports are available from the Electrical Research Association, Thorncroft Manor, Dorking Road, Leatherhead, Surrey; price 10s 6d each.

High Fidelity Loudspeaker Enclosures by B. B. Babani gives twenty designs (mainly American) including folded horns, reflex cabinets of small size or with horn-loaded ports and the Karlson tapered slot enclosure, and also general construction and design hints. Pp. 46; Figs. 25; Price 5s. Bernards (Publishers), Ltd., The Grampians, Western Gate, London, W.6.

Definitions and Formulæ for Students: Radio and Television Engineering by A. T. Starr. Fourth edition includes typical circuits. Pp. 65; Figs. 47. Price 2s. Sir Isaac Pitman and Sons, Ltd., Parker Street, London, W.C.2.

Brimar Radio Valve and Teletube Manual No. 7, includes information on new valve types previously supplied as separate data sheets. Pp. 336, Price 6s. Standard Telephones and Cables, Ltd., 63, Aldwych, London, W.C.2.

High Fidelity: A Practical Guide, by Charles Fowler. Basic acoustic theory leads to discussion of all types of units (including radio tuners) for high-quality sound reproduction, with emphasis on criteria for judgment and comparison. Pp. 310; Figs. 113. Price 37s or 4 dollars 95 cents. McGraw-Hill Book Co. Inc., 95, Farringdon Street, London, E.C.4, or 330, West 42nd Street, New York 36.

News from the Industry

Elliott-Automation, Ltd., is the name of the holding company which now links the recently merged interests of Elliott Brothers (London), Ltd., and Associated Automation, Ltd. The Elliott-Automation group includes among others the following subsidiaries: Electroflo Meters, Hall Telephone Accessories, Micanite & Insulators, and British Industrial Plastics. In addition there are the various divisions of Elliott covering computing, guided missiles, microwave instruments, aviation instruments, Swartwout electronic control gear and nucleonics.

Computer consultancy service is now offered to industry by the analytical department of Short Brothers & Harland at 208a, Regent Street, London, W.1. The department is equipped with four Short general purpose analogue computers and a recently installed English Electric DEUCE digital computer.

I.T.A.'s North-Eastern transmitter, at Burnhope, five miles south-east of Consett, Durham, will be equipped by Marconi's with vision and sound transmitters, combining units, and programme input equipment. They will also supply the twin 8-stack horizontally-polarized directional aerials to be mounted on a 750-ft mast.

Ferranti's 75 years of progress is traced in a special issue of *The Ferranti Journal*. Most of the space is naturally devoted to the company's interests in power engineering but there are two articles dealing with its more recent entry into the fields of computers and semiconductor devices.

Ambassador-Baird.—Changes are announced by Camp Bird Industries for the marketing of both Ambassador and Baird receivers which are now manufactured at the Ambassador works, at Brighouse, Yorks. The distribution of Baird receivers and tape recorders (through a limited number of wholesalers) will be centred at Camp Bird House, Dover Street, London, W.1. Ambassador will continue to be distributed direct to dealers from Brighouse. Eric Gamble, sales director of Camp Bird Industries, has joined the board of Ambassador Radio and Television, Ltd.

Hartley Baird Group, which includes Ambassador, Duratube & Wire, Hartley Electromotives and P.C.D. (Printed Circuit Development), incurred a loss of £75,000 during the sixteen months ended last April. This is reported in the review of John Dalgleish, chairman of Camp Bird, Ltd., who have a 64% holding in the group.

Standard Telephones & Cables and their associates Bell Telephone Manufacturing Co., Antwerp, have been awarded the contract to supply the coaxial cable, three submerged repeaters and terminal equipment for the Anglo-Belgian submarine cable telephone scheme, planned for introduction in time for the opening of the Brussels International Exhibition next April. The scheme provides for 120 two-way telephone channels using a frequency band of 60 to 552 kc/s in one direction and 672 to 1164 kc/s in the other. The repeaters, 9ft long and 10in diameter, are similar to those supplied by S.T.C. for the Newfoundland-Nova Scotia section of the trans-Atlantic telephone cable.

S.T.C. and their Paris associates Le Matériel Téléphonique, have been awarded the contracts for the supply and installation of the s.h.f. transmission equipment and aerials for the recently announced cross-channel radio relay system for multi-circuit telephony and television. The terminal stations will be near Folkestone and Lille with intermediate repeaters in France. The service, which is scheduled for introduction early in 1959, will provide two channels each capable of carrying 600 telephone circuits and two channels each suitable for two-way 819-line television.

Marine Radar.—Since Decca entered the marine radar field in 1950 they have received orders for fitting over 7,000 vessels. The estimated number of radar-fitted ships throughout the world is between 15,000 and 16,000.

British Communications Corporation is supplying the 15-watt base station and ten 5-watt mobile transmitter-receivers for the ambulance service of the Halifax Borough Council. B.C.C. has recently cooperated with the manufacturers of the Vespa motor scooter, and H. Miller, Ltd., generator manufacturers, to equip scooters with radio for police use. The reference in last month's issue to the use of B.C.C. radio-telephone equipment for the Newport railway marshalling yard should have been in the past tense.

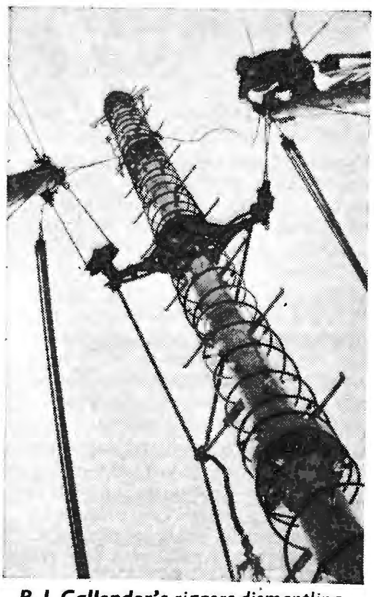
Aveley Electric, Ltd., of Aveley Industrial Estate, South Ockendon, Essex, have been appointed agents in the United Kingdom for the Narda Corporation, of New York, and the W. German companies Gossen, of Erlangen, and Electronic G.m.b.H., of Munich. Narda specializes in microwave components, Gossen in pointer instruments and Electronic G.m.b.H. in carbon film resistors.

Westinghouse Brake and Signal Company announce a new arrangement with Westinghouse Electric International of New York for the exchange of research information on semi-conductors. A new branch of the works at Chippenham has been built, with elaborate air conditioning, for the production of silicon and germanium power rectifier elements.

Rosite, Ltd., has been formed as a subsidiary of the Plessey Co. for the production of the cold moulded plastic Rosite (see Technical Notebook, p. 596) under an agreement recently made with the Rostone Corporation, of Lafayette, Indiana, U.S.A. The company is operating from Kembrey Street, Swindon.

Livingston Laboratories, of Retcar Street, London, N.19, have been appointed exclusive representatives in the U.K. and Eire by the tube division of Varian Associates, of Palo Alto, Cal. The agreement with the previous representatives, Rocke International, was terminated in June.

Winston Electronics, Ltd., Shepperton, Middlesex, have been appointed sole United Kingdom agents for a number of industrial electronic control instruments manufactured by Beckman Instruments, G.m.b.H., of Munich, Germany, and Beckman Instruments, Inc., of Fullerton, California, U.S.A.



***B. I. Callender's** riggers dismantling the helical Band V aerial at the E.M.I. works at Hayes, Middlesex, for re-erection on the Alexandra Palace mast for the u.h.f. television tests recently started by the B.B.C.*

Marconi closed-circuit television is being used at a branch of the Royal Marsden Hospital, London, to assist in the deep therapy radiation treatment of patients. The equipment is used in conjunction with a radio-active caesium source and permits the treatment to be carried out by remote observation to safeguard doctors and radiographers against harmful long-term excess radiation.

Hivac, Ltd., are marketing an augmented range of directly-heated sub-miniature valves many of which are exact equivalents of American types. The range (with U.S. equivalent in parenthesis) includes XFY14, output pentode (5672); XFR1, r.f. amplifier pentode (1AD4); XFR3 r.f. oscillator triode (5676) and XR4 r.f. power amplifier (6397).

S.T.C. have installed sound reinforcement equipment in the conference hall of the Trades Union Congress Memorial Building, Great Russell Street, London, W.C.2. Speeches from the dais are radiated by two "slot diffuser" loudspeakers behind the panelling above the speaker, but for speeches from the "floor" loudspeakers at the rear of the hall are brought into circuit and the others muted.

P.A.M., Ltd., of Merrow Siding, Guildford, installed a Pye industrial camera in the Grocers' Hall, London, which was linked by G.P.O. cable to the Mansion House where they had set up three large-screen (4 ft by 3 ft) Nera forward-projection receivers to enable delegates to watch as well as hear speakers at the recent Coal Utilization Council's convention luncheon.

Decca windfinding radar, manufactured under licence by the Société d'Optique, de Mécanique, d'Electricité et de Radio, is to be supplied for 14 meteorological stations in France and its colonies.

Hudson Electronic Devices, Ltd., are supplying 100 walkie-talkie receivers to the G.P.O. They will be used during investigations to locate equipment causing radio interference.

Videotape Patents.—The Radio Corporation of America and Ampex Corporation have signed an agreement for the exchange of patent licences covering vision-on-tape recording and reproducing systems for both monochrome and colour.

Oryx Electrical Laboratories, Ltd., of 98 Dominion Road, Worthing, Sussex, manufacturers of Oryx soldering instruments, are setting up their own home sales organization and orders should now be addressed as above.

Morganite Resistors, Ltd., who just under 10 years ago moved to the Bede Trading Estate, Jarrow, have transferred to a new factory of some 25,000 square feet alongside the original one.

Solartron's first production model of their electronic reading automaton (ERA) has been bought by Boots the chemists. It will be installed at their head office in Nottingham to "read" the sales recorded on the cash register rolls from the firm's 1,300 branches.

Miles Electronics, Ltd., has been formed by F. G. Miles, Ltd., the aircraft manufacturers, of Shoreham, in association with the Lombard Development Corporation. The new company has grown from the Miles electronics division and is at present mainly concerned with the design and construction of flight simulators and analogue computers.

RCA Great Britain have supplied sound reproducing equipment, including pre-amplifier, power amplifier, and f.m. tuner, for No. 10 Downing Street. The equipment was originally installed for the Conference of Prime Ministers, but is now used for the play-back of recordings made at cabinet meetings.

Ross, Courtney & Co., Ltd., manufacturers of components, wire, terminals and accessories, who are this year celebrating their diamond jubilee, have opened an extension to their Ashbrook Road Works, Holloway, London, N.19. This is the second extension in four years. The company is a subsidiary of the Southern Areas Electrical Corporation group, of which P.A.M., Ltd., is also a member.

OVERSEAS TRADE

C.R. Tubes.—£10,000 worth of 21-inch rectangular c.r. tubes are being supplied by Siemens Edison Swan, Ltd., to the Campagnia Commercial de Cinematogafia, of Milan. They will be used in television chassis made by E. K. Cole, Ltd., which are being housed in cabinets of Italian manufacture.

Duplicated radar equipment for approach control and general surveillance at the Luxembourg airport is being supplied by Cossor Radar & Electronics, Ltd. The order also calls for triplicate display units, two of which will be remotely controlled.

Sound reproducing equipment for the simultaneous translation system in the new headquarters of the United Nations Educational, Scientific and Cultural Organization in Paris is being installed by Pamphonic Reproducers. The installation, which provides for a five-language translation system, includes amplifiers, control consoles, 500 microphones and 2,000 headphones.

Communications equipment, including three 3.5-kW h.f. transmitters (with their associated drive, keying and monitoring equipments), a 30-kW linear amplifier and receivers, has been ordered from Marconi's for the Khartoum Communications Centre in the Sudan.

A complete television station for operation in Band III has been purchased from Marconi's by Radio Valencia of Venezuela. It comprises a 2-kW vision transmitter, a 1-kW sound transmitter, aerial array, studio equipment, film scanner, vision and sound links and 3-camera o.b. unit. Marconi's have also recently supplied a 2-kW medium-frequency sound broadcasting transmitter for unattended operation in Venezuela.

British Physical Laboratories, who exhibited at the recent Canadian I.R.E. Convention, have appointed R.O.R. Associates, of Toronto, as their sole distributors in Canada. The United Mineral & Chemical Co., of New York, have been appointed distributors for the United States east coast and mid-west. Dr. V. A. Sheridan, managing director of B.P.L., has been touring North America and attended the Toronto Convention.

South Africa.—The Board of Trade is considering erecting a pavilion for the annual South African Rand Easter Show. A sixth of the available space would be occupied each year by a prestige display (among the subjects suggested is electronics) and the remaining 8,000 square feet would be available to manufacturers and industrial organizations. Those interested in the project, which would be introduced in 1959, should communicate without delay with the Export Publicity and Fairs Branch, Lacon House, Theobalds Road, London, W.C.1.

NEW ADDRESSES

Siemens Edison Swan have opened a cathode-ray tube service depot at Fourth Avenue, Team Valley Trading Estate, Gateshead, Durham (Tel.: Low Fell 75463). It will deal with c.r. tubes only; valves must be returned to the service depot at Brimsdown, Middlesex. The company has also opened offices, showroom, warehouse and maintenance workshop, at 76-80, Sherlock Street, Birmingham.

E.A.P. (Tape Recorders), Ltd., recently moved from 9 Field Place, London, E.C.1, to a new factory at Bridge Close, Old Church Road, Romford, Essex (Tel.: Romford 62366).

Direct TV Replacements have moved from 134 to 138, Lewisham Way, New Cross, London, S.E.14 (Tel.: Tideway 6666). They have installed an Ipsophone recorder for taking orders when the office is closed, for which the telephone number is Tideway 6668.

Alma Components, Ltd., have moved their works and offices from 165 Ossulston Street, London, N.W.1, to 551 Holloway Road, London, N.19 (Tel.: Archway 0014).

DECEMBER MEETINGS

LONDON

3rd. I.E.E.—"Some aspects of half-wave magnetic amplifiers" by G. M. Ettinger; "Some transistor input stages for high-gain d.c. amplifiers" and "A transistor high-gain chopper-type d.c. amplifier" by Dr. G. B. B. Chaplin and A. R. Owens; and "Dekatrons and electro-mechanical registers operated by transistors" by Dr. G. B. B. Chaplin and R. Williamson at 5.30 at Savoy Place, W.C.2.

10th. Institute of Physics.—"Infra-red and microwave modulators using free carriers in germanium" by Dr. A. F. Gibson (R.R.E.) at 5.30 at 47 Belgrave Square, S.W.1.

11th. Physical Society.—Reports on "The Paris meeting on colour television, 1957" by L. C. Jesty; "The meeting of the C.I.E. Working Party on calorimetry, Teddington, 1957" by Professor W. D. Wright; and "The symposium on visual problems of colour, Teddington, 1957" by Dr. W. S. Stiles at 3.30 at Imperial College, S.W.7.

11th. I.E.E.—"A flying-spot film scanner for colour television" by H. E. Holman, G. C. Newton and S. F. Quinn at 5.30 at Savoy Place, W.C.2.

11th. Institute of Physics.—"Irregularities and movements in the ionosphere" by Dr. B. H. Briggs (Cavendish Laboratory) at 6.0 at 47 Belgrave Square, S.W.1.

13th. Television Society.—"Dressing television: cabinet design" by L. J. Griffen (Kolster Brandes) at 7.0 at 164 Shaftesbury Avenue, W.C.2.

16th. I.E.E.—"Electronics and automation—electronics in the textile industry" by K. J. Butler at 5.30 at Savoy Place, W.C.2.

16th. British Computer Society.—"Parallel programming: a study of a new technique in digital computer programming" by Dr. S. Gill (Ferranti) at 6.15 at Northampton College of Advanced Technology, St. John Street, E.C.1.

17th. I.E.E.—"Recent uses of ultrasonics in investigating the characteristics of materials" by Dr. J. Lamb at 5.30 at Savoy Place, W.C.2.

18th. Brit. I.R.E.—"Recent developments in electronic instrument design" by E. Garthwaite and A. G. Wray at 6.30 at the London School of Hygiene, Keppel Street, W.C.1.

20th. B.S.R.A.—"Lightweight pick-up design" by Stanley Kelly at 7.15 at the Royal Society of Arts, John Adam Street, Adelphi, W.C.2.

BIRMINGHAM

2nd. I.E.E.—"Electronic control of machine tools" by D. T. N. Williamson at 6.0 at the James Watt Memorial Institute, Great Charles Street.

13th. Society of Instrument Technology.—"Electronic instrumentation trends and implications" by R. J. Redding (Evershed & Vignoles) at 7.0 at Regent House, St. Phillips Place, Colmore Row.

CAMBRIDGE

3rd. I.E.E.—"The Mullard radio astronomy observatory" by M. Ryle at 8.0 at the Cavendish Laboratory.

CARDIFF

4th. Brit.I.R.E.—"Demonstrations on aerial circuits" by H. V. Sims at 6.30 at the Cardiff College of Technology and Commerce, Cathays Park.

6th. Institute of Physics.—"Microwave triodes" by Professor M. R. Gavin (University College of North Wales) at 5.15 in the Physics Department, University College of South Wales.

CHATHAM

12th. Institution of Production Engineers.—"The practical uses of electronics in industry" by K. A. Zandstra, at 7.30 in the Assembly Room, Sun Hotel.

CHELMSFORD

10th. I.E.E. (Graduate and Student Section).—"Television film recording" by E. J. Stocks at 7.0 at the Public Library.

EDINBURGH

3rd. I.E.E.—"Infra-red radiation" Kelvin lecture by Dr. G. B. B. M. Sutherland at 7.0 at the Carlton Hotel, North Bridge.

13th. Brit.I.R.E. — "High-quality sound reproduction" by R. E. Cooke at 7.0 in the Department of Natural Philosophy, University of Edinburgh.

GLASGOW

12th. Brit.I.R.E. — "High-quality sound reproduction" by R. E. Cooke at 7.0 at the Institution of Engineers and Shipbuilders, 39 Elmbank Crescent.

LEEDS

3rd. I.E.E.—"The use of transistors in radio and television" by Dr. A. J. Biggs and E. Wolfendale at 6.30 at 1 Whitehall Road.

MANCHESTER

11th. I.E.E.—"Ferrites" by Dr. D. H. Pringle at 6.45 at the Engineers' Club, 17 Albert Square.

12th. Brit.I.R.E.—"Process heating" by M. O'C. Horgan at 6.30 at the Reynolds Hall, College of Technology, Sackville Street.

NEWCASTLE

2nd. I.E.E.—"Recent uses of ultrasonics in investigating the characteristics of materials" by Dr. J. Lamb at 6.15 at King's College.

11th. Brit.I.R.E. — "Stereophonic sound and tape recorders" by D. H. McBean at 6.0 at the Institution of Mining and Mechanical Engineers, Neville Hall, Westgate Road.

PLYMOUTH

5th. I.E.E.—"The B.B.C. sound broadcasting service on very-high frequencies" by E. W. Hayes and H. Page at 3.0 at the Electricity Showrooms, New George Street.

LATE-NOVEMBER MEETINGS

27th. Institute of Physics.—Symposium on "The design of physics research laboratories"; speakers will include B. S. Fleming-Williams (Sylvania-Thorn Colour Television Laboratories) and J. G. Cornwell (G.E.C. Research Laboratory), at 2.30 in the Lecture Theatre, Royal Institution, 21 Albemarle Street, London, W.1.

28th. Institution of Electronics.—"The high fidelity reproduction of sound" by C. Brown (Philips) at 6.30 in the Assembly Hall, University of London Institute of Education, Malet Street, London, W.C.1.

29th. Brit.I.R.E.—"Automatic programming" by Dr. P. M. Woodward at 7.0 at the North Gloucestershire Technical College, Cheltenham.

RANDOM RADIATIONS

By "DIALLIST"

'he Live Chassis

N a recent issue of the New York 'adio *Electronics* the editor, Fred hunaman, had a strongly worded 'ticle calling attention to the dan-ers of the live chassis in domestic iains receiving equipment. I'm ompletely with him, for I've always garded the transformerless set run om a.c. mains as an electrical orror. If Mr. Shunaman calls them thal when the standard a.c. mains ipply in his country is 110-117 olts, how much more so are they ere with mains voltages ranging om 200 to 250 volts? Probably ell over half of the millions of sound id television sets in use here to-day et their a.c. mains supplies *via* 2-pin lugs and sockets, or even lamp ocket adaptors. It's therefore a fifty-fty chance that the chassis is con-ected to the live wire. Heaps of olk make a practice of switching off ieir sets at the mains. If—and in lder houses it's rather a big if—the witch breaks the live lead, the chassis ien automatically becomes dead. ut if it's the neutral that is broken, ie chassis and one wire of the often onsiderable length of flex between and the socket are live. Those who 'ill fiddle about inside their sets 'ithout knowing the faintest thing bout them run no small risk and iere's always the possibility that a iult may develop when the set is out f use and cause a fire. Things are ife enough if only people will follow ie makers' instructions and switch f at the set, for that switch breaks oth leads.

Vhat Do You Think?

The double-wound mains trans-ormer has two such big advantages iat one wonders why more manufac-irers don't use it, in their more ex-ensive models at any rate. Its core connected to the chassis and if this well and truly earthed there's no iance of the chassis becoming live. gain, a mains transformer makes possible to do away with those orrible chains of valve heaters. If one eater in a series chain burns out, all ease to light up and the serviceman's isk of locating the culprit isn't cactly made easy. When a valve's ithode is returned to chassis the d. between it and the heater may be undesirably large. I wonder if any manufacturer has toyed with (or even tried out) the idea of building in a constant-voltage transformer? In many parts of the country there are considerable drops in the mains voltage at times. They can be large enough to effect the working of television sets seriously either by giving rise to picture shrinkage or by upsetting the sync.

Band V Possibilities

BY the time you read this experimental television transmissions in Band V should be under way. The idea behind this joint effort initiated by the Television Advisory Committee and carried out by the B.B.C. is first to discover whether such ultra-high frequencies can be used for TV broadcasting in this country. Both 405-line and 625-line definitions are to be used so that the results can be compared. To me it seems that with Band V we've a heaven-sent opportunity of developing a really high-definition system. Naturally that can't be done in Bands I or III; but in Band V such a service could be developed with the same relation to the present B.B.C. and I.T.A. services as in sound broadcasting the v.h.f./f.m. transmissions bear to those on the medium-wave and long-wave bands. There's no need for a man to exchange his a.m. receiver for an f.m. set unless he chooses to; but if he wants the improved service, it's there waiting for him. In the same way, the potentially higher definition would be there for anyone who cared to go in for a Band V television receiver. Though (and probably because) we led the world by getting the first TV service going, to my mind it's a sad fact that our 405-line standard is the lowest to be found anywhere. In Band V we could develop something even better than the admirable 819-line French system. Let's hope we have a shot at it!

The Shape of Things That Came

AWAY back in 1936, in the December 11th issue of the then weekly *Wireless World*, I was rash enough to forecast what the future was likely to have in store for sound and television in a dozen years from then. The paragraph in "Random Radiations" ended: "If you want a fine chance of hurling the epistolary brick at me, file this number of *W.W.* and write to tell me how wrong my predictions proved to be!" One reader did the filing and he has now been kind enough to send me the cutting —without the brick. My dates were thrown out by the war, which closed down television and prevented progress from being made in domestic sound receivers. Otherwise I seem to have been a fairly reliable prophet. I wrote that I expected that the bulk of local listening would be on v.h.f. and that the quality would really approach perfection owing to the much wider range of modulation frequencies that it would be possible to use. Some sets would be for v.h.f. only. I was over-optimistic in believing that the standard domestic set would by then be a combined television and v.h.f. set, though things now seem to be tending that way. My only big bloomer was the statement that I didn't believe that the television set of the near future would contain a cathode-ray tube. Even now I'm still not convinced that line-by-line scanning on the screen of a modified form of oscilloscope (which is what the TV set is) is the final answer to television transmission and reception. It's admittedly a pretty good answer, but I firmly believe that a better one will be found, though I'm not going to risk this time forecasting a date.

A New Pastime?

DX WORK on v.h.f. sound broadcasting stations seems likely to become almost as popular a hobby as it once was in other broadcasting bands. Readers living in many different places write to tell me of some quite remarkable experiences. One of them lives at Aylesbury, Bucks, which doesn't lie very high and there's a good deal of hilly ground in some directions. My correspondent uses a dipole-cum-reflector indoor aerial directed on Wrotham. His record shows occasional good reception from Wenvoe, particularly in the morning and evening. Others recorded are Norwich, Holme Moss and Sutton Coldfield among the B.B.C. stations. Between June 14th and 22nd he logged German, Dutch and Italian stations. Conditions became unfavourable from then until early September, since when he has been receiving three French stations.

Hearing Electrically

A NUMBER of readers concerned professionally with hearing and auditory perception have asked for further information on the experiments on direct electrical stimulation of hearing, to which I referred in the September issue. The work was undertaken by two French doctors, Charles Eyriès and André Djourno, who recently communicated their findings to the Academy of Medicine, Paris. Their work was brought to my notice by a note in the *Sunday Times* of July 14th.

UNBIASED

By FREE GRID

"Ears Have They, and Hear Not"

AT one time it used to be the custom among the semi-literate to clinch an argument by saying "I've seen it in print." The "print" in question was usually to be found in one of the more sensational newspapers. If it appeared in a newspaper it *must* be true; so the upholders of this argument-clinching cliché used to think. A newspaper to them meant as much as the "Guid Book" to a kirk-going Caledonian.

Those times have passed however, for the authoritarian position of the newspapers has long ago been undermined by the B.B.C. Nowadays the criterion of truth is "the wireless," and the educational status of those who believe what they hear on "the wireless" is considerably higher than semi-literate. The word of the B.B.C. is so powerful in its effect on certain minds that it is almost frightening.

A month or two ago as Mrs. Free Grid and I sat in front of our modern infra-red fire, she suddenly gave a snort of disgust as she looked up from the October issue of *W.W.* which had just come to hand. This was the issue in which "Cathode Ray" discussed certain scientific theories, past and present, including the old and popular one of an all-pervading ether through which wireless waves were supposed to travel. "Surely," said Mrs. Free Grid, "even *he* must be aware that wireless waves are airborne and always have been, as the B.B.C., who surely must know, wouldn't constantly use the expression 'on the air'?"

Naturally I made a spirited defence of "Cathode Ray" but only succeeded in losing scientific caste myself, and now he has let me down badly by making a statement in which even I cannot support him. He states in the November issue that sound "is a physical disturbance that would exist even if there were no living creatures to hear it." In my view it is only necessary to substitute the word pain for sound and feel for hear in order to show that "Cathode Ray's" statement won't hold water.

I'm not trying to dabble in philosophy with its theory of pan-subjectivism when I say that pain and sound would cease to exist if there were no living creatures to feel and hear them. In the absence of *living* creatures the physical disturbances which cause the mental phenomena of pain and sound would, of course, still exist.

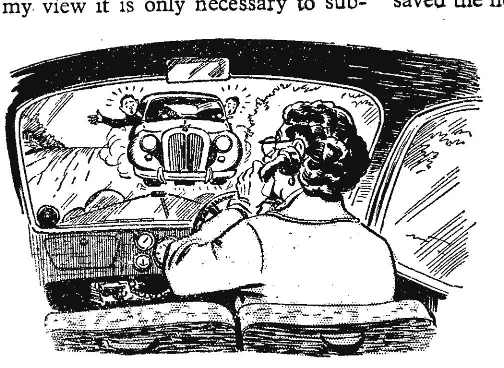
'Phoning While You Speed

THE modern generation finds it hard to believe that there was ever a time when there was no such thing as sound broadcasting and television. In the same way, I think, the generation of a decade or so hence will find it hard to believe that our cars were not connected by radio to the national telephone system.

It would be, technically speaking, quite possible for our cars to be "on the phone" today if only the G.P.O. would do something about it. As it is, I pay 5s, register myself as a business with my H.Q. at home, and I can then apply for a mobile radio licence to cover radio-telephony between my home and car, but my ambition is to be able to call any telephone subscriber from my car.

This could be so easily arranged if the P.M.G. would erect a suitable transmitting and receiving station on the roof of every telephone exchange. Then by calling this exchange-roof station I could be plugged into the line of any subscriber just as though I were ringing from home. Not only could I call any subscriber but I could communicate with any other car, provided that it happened to be within wireless range of a telephone exchange.

I think that a start could be made by the A.A. and R.A.C. who could rig up a radio link on the roofs of their phone boxes for night use so that stranded motorists would be saved the necessity of trudging a mile to the nearest box as I had to do recently after midnight in order to put in a call for help. Unlike my proposed G.P.O. exchange arrangement, this roadside radio link between stranded car and breakdown service would have to be unmanned and so completely automatic; but what of that?



New road hazard

The only snag in my whole idea of cars-on-the-phone is that women drivers would certainly try to drive and carry on an interminable telephone conversation simultaneously. This would mean that during the telephone talk the car would be virtually unmanned—or should I say unwomanned—and this would constitute another road hazard.

For some years the G.P.O. has provided a radio-telephone link so that small craft in the Thames estuary could be connected to the national telephone system. Why can they not extend the idea for cars in the manner I have suggested?

The Old W.W. Tie

WHEN visiting the National Radio Show and other quasi-radio gatherings like the Audio Fair I often feel that those of us who have some general interest in and knowledge of the scientific side of radio ought to have some distinguishing emblem whereby we could recognise our fellow savants and be picked out by the stand attendants from the milling crowd who are only interested in the programmes.

I can think of nothing better than to follow the example of our public schools and other famous institutions by sporting a specially designed "Old *Wireless World* Tie," for it need hardly be said that anybody having any wireless engineering qualifications at all is a regular reader of this journal. Indeed, I recollect a former Editor of *W.W.* saying in pre-war days that to be a regular reader of *W.W.* was a qualification in itself. I would suggest that anybody who could produce proof that he was a reader of ten years standing should be entitled to wear the tie which would, of course, be sold only to those who could produce a certificate signed by the Editor.

Those of us of more than ten years standing would be entitled to wear on it a bar for every extra period of five years. Those who could produce proof that they had been readers since the first number (April 1911) without missing an issue would be entitled to receive a complementary copy each month for the rest of their lives; maybe they would deserve it.

First it is necessary to settle the question of a suitable design and here is where I need the assistance of some of you with heraldic experience, as thing like "bends sinister" and "gules argent" are just Greek to me. As you will gather I want something completely out of the ordinary in neckties; something like a coat of arms complete with Latin motto such as Audio, Video, Olfaciam, for I am convinced that the radio transmission of smell will one day be achieved.

If enough of you write to the Editor about the suggestion something is bound to happen, as Editors are as much susceptible to public opinion as politicians are at election time.*

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* Observation noted: no comment—ED.