Wireless World

ELECTRONICS, RADIO, TELEVISION

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Transistor R.F. Stages for Portable Receivers

This circuit indicates the use of Mullard r.f. transistors, types OC44 and OC45—in the frequency multiplying and i.f. amplifying stages of an all-transistor portable radio receiver. These transistors are intended primarily for the types of application they have in this circuit. The OC44 is used as a self-oscillating mixer and each OC45 functions as an i.f. amplifier.

Frequency Changer—OC44

The input signal for the self-oscillating mixer stage is taken from the aerial coupling coil (by way of the selector switch) to the base—the most sensitive input point—of the OC44. Oscillator feedback is taken from the collector of the transistor to the emitter through low-impedance windings on the oscillator coil.

The oscillator tuned circuit is similar to the types used in valve receivers, since the reflected capacitance from the transistor is very small (about 1pF). The Q of the oscillator coil is somewhat higher than in valve receivers, however, to allow for transistor damping. A shaped oscillator section in the tuning capacitor is used to obtain correct tracking of the aerial and oscillator circuits. The value of tuning capacitance is not critical, although it must be sufficient to provide the desired frequency coverage. The values of capacitance chosen are 175pF and 123pF for the aerial and oscillator sections respectively, and a screen is provided between the sections to reduce any stray capacitance between them.

To ensure that the oscillator starts easily, the OC44 is biased initially for Class A operation with the normal stabilisation circuit. However, as the amplitude of oscillation increases, rectification of the oscillator voltage at the emitter causes a steady voltage to be developed across the resistance and bypass capacitance in the emitter circuit. This voltage tends to bias the transistor into Class B operation, and also stabilises the amplitude of oscillation. At the same time, this voltage increases the quiescent current taken by the transistor.

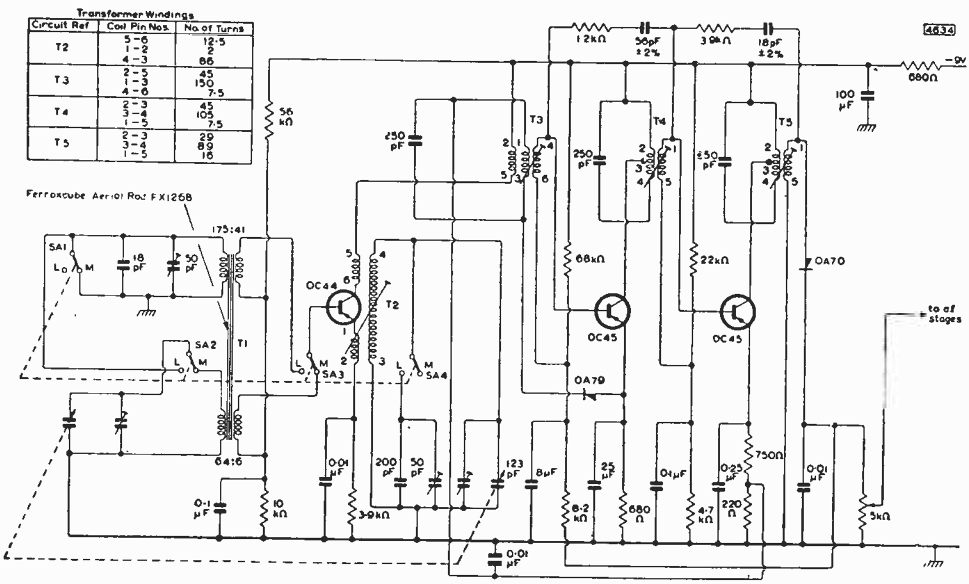
A minimum level of noise is achieved when the direct emitter current in the frequency changer is about 0.25mA. In addition, the fall in gain and the phase shift in the OC44 (up to the maximum oscillator frequency of 2.07Mc/s) are small with this value of current. Furthermore, the effect of spreads in the h.f. performance of the transistor is also small. Consequently this value of 0.25mA (it rises to 0.3mA when the oscillator is functioning) has been chosen for the emitter current of the OC44.

I.F. Amplifier—OC45

The internal feedback which can appear in a transistor used for h.f. amplification can complicate the design of an i.f. stage. This feedback can produce oscillation in the same way that oscillation is caused by the anode-to-grid capacitance of a triode used as a tuned amplifier. Even if oscillation does not occur, this feedback can cause serious distortion of the frequency response of the amplifier, so it is obviously desirable to neutralise it in some way.

It is possible to achieve neutralisation by introducing an external feedback path containing suitably chosen values of resistance and capacitance. When both the purely resistive and the reactive elements of the internal feedback path have been neutralised completely, the result is known as *unilateralisation*. With unilateralised stages, the design of the amplifier becomes relatively straightforward.

The i.f. amplifier consists of two OC45 transistors each connected in unilateralised grounded-emitter stages. The external feedback components are the two resistors (1.2 and 3.9kΩ) and the two capacitors (56 and 18pF) drawn above the supply line in the circuit. The power gain of the first stage of the i.f. amplifier is 31.2dB when there is no a.g.c. action in the circuit, and that of the second stage is 34dB. Neither of the values of gain exceeds a quarter of the loop gain necessary to produce oscillation when the feedback capacitors are at the extreme of the tolerance range, and consequently the stability of the amplifier is high.



Transformer Windings

Circuit Ref	Coil Pin Nos.	No. of Turns
T2	5-6 1-2 4-3	12·5 2 86
T3	2-5 1-3 4-6	45 150 7·5
T4	2-3 3-4 1-5	45 105 7·5
T5	2-3 3-4 1-5	29 89 16

FEBRUARY 1958

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A Change of Wind?

THE announcement that Sir Lawrence Bragg has consented to act as chairman of the new Frequency Advisory Committee, which has been set up by the Postmaster-General to advise him on the broad aspects of frequency allocation, offers some hope of a more liberal approach to this problem than has been evident in the past.

The Committee is broadly based and it is difficult to imagine any interest which will not be represented by one or more of the appointed members.* Discussion in open committee of rival claims is in itself an important advance over the previous practice of independent consultation between the P.M.G. and his competitors for channel space. The inclusion of Post Office representatives in the list of members of the Committee will be a matter for satisfaction if it means that the P.M.G. will now be called upon to state a case for his own requirements on equal terms with other users.

There remains the vexed question of the Armed Services who may offer "security" as sufficient excuse for refusing to justify a claim for particular frequencies. Priorities of this kind can be settled only at Cabinet level, where arguments should be assessed and presented by a Minister who is not directly responsible for either defence or communications, but who has a call on the best scientific and technical advice available. The suggestion, made by C. I. Orr Ewing, M.P., as far back as 1955† that the Lord President of the Council would be well qualified to perform these duties still seems to us to be a good one.

As far as civil claims are concerned, the new committee is a step in the right direction, extending as it does the work already initiated by the Mobile Radio Users' Association and the R.C.E.E.A. Frequency Planning Advisory Committee. The new chairman brings to his task a clear mind and the gift of lucid expression; it goes without saying that he has the basic scientific knowledge to get quickly to the technical roots of the problem. We wish him well in the complex and onerous task he has undertaken.

If by goodwill and a rational approach this committee, in spite of its size, shows itself capable of working quickly to wise and practicable conclusions it may well pave the way to the establishment of a supra-departmental British Communications Commission with executive powers which would take over the P.M.G.'s present invidious duties in frequency allocation.

Simpler Units

IN the January issue (p. 50) "Free Grid" complained of the clumsy fractions which are commonly used to express the standardized speeds at which magnetic recording tape is transported past the heads, and suggested the use of a new unit (the "Stille") to represent, say, a speed of $1\frac{7}{8}$in/sec. A correspondent in this issue gives an authoritative account of the origin of these speeds, but finds it difficult to see any practical advantage in using the proposed geometrical progression of whole numbers (e.g., 1, 2, 4, etc. "Stilles" instead of $1\frac{7}{8}$, $3\frac{3}{4}$, $7\frac{1}{2}$ etc. in/sec).

In this matter, our sympathies are with "Free Grid" who has to write and our printers who have to set these irritating fractions. The flying fraternity have long since given up writing "981 cm/sec/sec" and "761.6 m.p.h. at sea level and 59°F" (or if this is not correct, something even more complicated): they just put down "g" and "Mach 1" and their colleagues know at once what they are talking about.

We are disappointed that "Free Grid" should have chosen to immortalize one of the commercial impresarios of magnetic recording rather than one of its scientific or technical worthies, but we appreciate his difficulty. Much as we should like to see Dr. Pfleumer (oxide-coated tapes) or Carlson and Carpenter (a.c. bias) honoured in this way, the possibility of contraction of the appropriate units to "pF" and "c.c." would be certain to cause misunderstanding. Any suggestions?

*A detailed list appears on the following page.

†See Wireless World, May, 1955, page 215.

WORLD OF WIRELESS

Frequency Advisory Committee

A FEW months ago the P.M.G. in a written reply to a question in the House of Commons stated that he was appointing a committee to advise him on the broad aspects of frequency planning. He has now announced the membership of the committee, and its terms of reference—"To advise the Postmaster General on the broad aspects of radio frequency planning with a view to the efficient use of the radio frequency spectrum and the economic development of equipment for that purpose by the radio industry."

Sir Lawrence Bragg, F.R.S., director of the Davy Faraday Laboratory of the Royal Institution, is chairman.

The members are:—G. Berry (nominated by the Association of Municipal Corporations), Cdr. K. B. Best (Home Office), Sir Harold Bishop (B.B.C.), Capt. C. F. Booth (Post Office), J. R. Brinkley (Pye Telecommunications), J. Clarricoats (R.S.G.B.), W. G Downey (M.o.S.), Sir Robert Fraser (I.T.A.), Supt. F. Gee (nominated by the County Councils Association), R. W. N. B. Gilling (M.T. & C.A.—Marine & Inland Transport), T E Goldup* (Mullard), Col. E. J. C. Harrison (British Joint Communication-Electronics Board), M. van Hasselt (S.T.C.—nominated by Telecommunication Eng'g. & Mftg. Assoc.), Capt. C. A. James (Admiralty), K. I. Jones* (Cossor), R. J. Kemp* (Marconi's), Air Comdre. H. G. Leonard-Williams (Air Ministry), Capt. L. P. S. Orr, M.P. (Mobile Radio Users' Association), G. F. Peirson (nominated by the Nationalized Fuel and Power Industries), C. G. Phillips (M.T. & C.A.—Civil Aviation), Dr. R. L. Smith-Rose (D.S.I.R.), Maj. Gen. L. de M. Thuillier (War Office), W. A. Wolverson (Post Office), Capt. F. J. Wylie (Chamber of Shipping), and E. Sharpe (Post Office), secretary.

* Nominated by the Radio Industry Council.

Guided "Missilry"

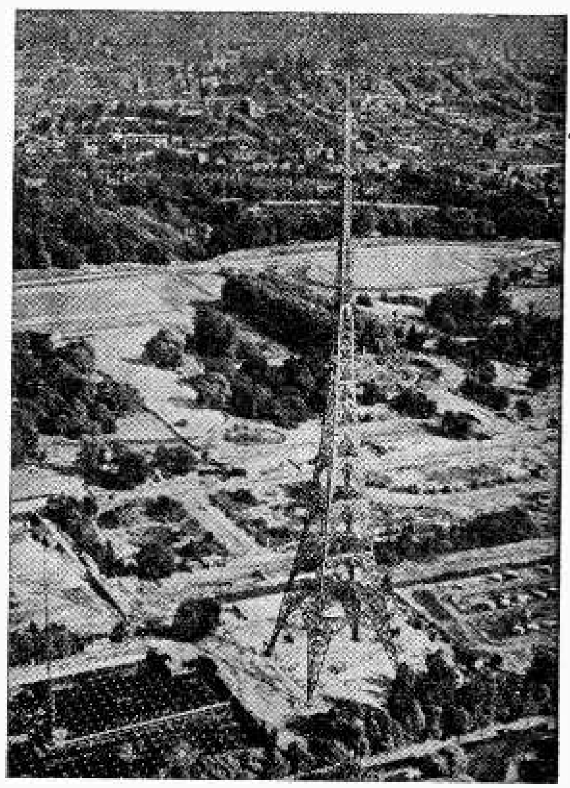
A FIRST course of instruction in the principles of guided weapon design and operation for post-graduate engineers and scientists from N.A.T.O. countries was started at the College of Aeronautics, Cranfield, Bucks., in October, 1956. Students are nominated by their Governments and in the second one-year course 24 students from seven foreign countries are participating. Two-thirds of the present students are serving officers.

Discussions on co-operative training have been held on both sides of the Atlantic and it has been suggested in America that a N.A.T.O. "missilry" training centre should be set up. It would seem that in the Cranfield courses we already have a nucleus which could be expanded to meet any future requirements.

Automation and Computation.—A consortium of some 20 organizations interested in automation and computation set up as the British Conference on Automation and Computation is to be organized as three groups, each covering a different aspect of the subjects. What is to be known as the British Group for Computation and Automatic Control, consisting of 23 member associations, has elected T. E. Goldup, this year's president of the I.E.E., as its chairman, with J. F. Coales, of the Society of Instrument Technology, as one of the vice-chairmen. Communications for the group should be sent care of the I.E.E., Savoy Place, Victoria Embankment, London, W.C.2.

Stereophonic Broadcasting.—Tests were conducted by the B.B.C. after normal broadcasting hours on January 13th and 14th using the Brookmans Park (m.w.) and Wrotham (v.h.f.) Home Service transmitters for one sound channel and the Wrotham Third Programme frequency and Crystal Palace TV sound carrier for the other. Further tests may take place, some possibly in broadcasting hours.

Exports Up Again.—Although figures for December are not available at the time of writing, it would appear from the figures for the first 11 months of the year that 1957 will have provided a record volume of radio exports. At the end of November the total was £39.7M, which is only £0.5M short of the figure for the whole of 1956.



B.B.C. Crystal Palace television tower dominates the South London landscape. At present two aerials are installed, one for Channel 1 and another, on top of the 710-ft tower, for experimental u.h.f. transmissions. Provision is made for installing two Band III aerials, the original design of the top-most having been amended at the Government's request to make provision for the possible installation of an I.T.A. aerial. In the left foreground is the temporary 200-ft mast initially used by the B.B.C. Both the mast and the tower were built by B.I. Callender's.

WIRELESS WORLD INDEX

The index to the material published in Volume 63 of *Wireless World* (1957) is now available. It includes both general and classified indexes, and is obtainable from our Publishers price 1s. (postage 3d). Cloth binding cases with index cost 7s. 6d. (postage and packing 1s. 6d.). Our Publishers will undertake the binding of readers' own issues, the cost per volume, including the index and binding case, being 22s. 6d., plus 2s. 6d. postage and packing.

Receiving Licences.—Domestic sound-only receiving licences current at the end of November totalled 6,688,720. Combined television and sound licences increased by 133,113, bringing the total to 7,657,184. Car radio licences totalled 327,818. The overall number of licences in the U.K. was 14,673,722—a decrease of 3,890 during the month.

Anglesey's v.h.f. station is to be built near Llanddona and is expected to be completed by the autumn. It will operate on 89.6, 91.8 and 94.0 Mc/s.

TV in Canada.—The Canadian Government is being urged by the Canadian Chamber of Commerce to set up an independent organization to control both government and independent television and sound broadcasting. At present the Canadian Broadcasting Corporation, which operates a sound and television service on the lines of the B.B.C. (except that they do have some sponsored programmes) also has the control over the allocation of channels to privately operated commercial TV and sound stations.

Australia, which at present has six television stations (one national and two commercial stations in both Sydney and Melbourne) is inviting tenders for the erection of stations in the other four State capitals, Brisbane, Adelaide, Perth and Hobart.

Brit.I.R.E. Council.—At the 32nd annual general meeting of the Institution, G. A. Marriott, director of the M.O. Valve Co., was re-elected president for a second year. The four vice-presidents, L. H. Paddle, J. L. Thompson, Prof. Emerys Williams and Prof. E. E. Zepler were also re-elected. To fill the four vacancies on the council the following were elected: A.V-M. C. P. Brown (Redifon), Col. G. W. Raby (Atomic Power Constructions), S. J. H. Stevens (Ministry of Supply) and A. H. Whiteley (Whiteley Electrical).

Semi-conductor Metallurgy.—A one-day symposium on "Metallurgical Aspects of Semi-Conductors" is being organized by the Institute of Metals. It will be held at the College of Technology, Gosta Green, Birmingham, on February 25th. Particulars are available from the Institute at 17, Belgrave Square, London, S.W.1. Tickets are not required for the meeting.

Higher technological courses, being held in 40 colleges in London and the Home Counties during the Spring and Summer terms, are outlined in the Bulletin of Special Courses in Higher Technology issued by the Regional Advisory Council for Higher Technological Education. They are mostly part-time evening courses but 18 full-time courses of not more than three months' duration are also included among the 260 listed. The 70-page booklet is obtainable from the Council at Tavistock Square, London, W.C.1, price 3s post free.

Radar Association.—A meeting of members of the Radar Association is being held on January 29th at which it is proposed to introduce the word "electronics" into the title of the Association.

Television Society's headquarters have been transferred to 166-170, Shaftesbury Avenue, London, W.C.2. The Society's meetings, however, will continue to be held in the Theatre of the Cinematograph Exhibitors' Association, 164, Shaftesbury Avenue, W.C.2.

Head Office of the Radio Officers' Union has been transferred to Radio House, 4-6, Branfill Road, Upminster, Essex. The telephone number is unchanged (Upminster 2321).

Perpetuating an error which appeared in the programme of the International Components Symposium at Malvern we referred in our note "Oxide Film Resistors" (page 596, December) to Dr. G. V. Planer's company as Planer Laboratories. It should be G. V. Planer, Ltd., of Sunbury-on-Thames, Middlesex.

A correction.—Livingston Laboratories ask us to say that in the advertisement on p. 30 of the January issue the sterling price of the Type 515 oscilloscope should be £303 and not £290.

Personalities

Vice-Admiral J. W. S. Dorling, C.B., M.I.E.E., is to retire on medical advice from the directorship of the Radio Industry Council, a position he has held since the formation of the council in 1946. Admiral Dorling had a distinguished career as a wireless officer in the Royal Navy. Between the two wars he served successively as fleet wireless officer, director of the signal department at the Admiralty, and captain of H.M. Signal School, Portsmouth. His retirement takes effect from October 31st.

Dr. W. R. G. Baker retired from the vice-presidency of the General Electric Company of America on reaching the age of 65 in November and has become vice-president of Syracuse University, in charge of research. Dr. Baker joined the company's engineering laboratory at Schenectady in 1917. His best-known contribution to the American radio industry is probably the direction of its two National Television System Committees, the first to establish standards for the American monochrome service and the second, appointed in 1950, to set up standards for what is now known as the N.T.S.C. colour system.

J. A. Smale, C.B.E., A.F.C., B.Sc., M.I.E.E., who retired last year from Cable & Wireless, of which he had been engineer-in-chief for 10 years, has been elected a fellow of the American Institute of Radio Engineers "for pioneering work in telecommunications." Since his retirement from C. & W., Mr. Smale has been technical consultant in telecommunications engineering to Marconi's and is part-time chairman of the Cyprus Inland Telecommunications Authority.

As a result of the reorganization of the special products division of Ultra Electric, **W. H. Medcalf,** A.M.I.E.E., becomes chief engineer, **R. M. W. Grant,** M.I.E.E., factory manager and chief executive in charge of all production activities, and **A. M. Pollock,** commercial manager. The division, which is concerned with the production of radar equipment, aircraft electronic equipment, and the well-known Sarah radio rescue beacon, is under the general management of **A. V. Edwards,** a director of the company. Mr. Medcalf, who joined Ultra from the G.E.C. Research Laboratories in 1945 as assistant chief engineer, has been deputy chief engineer since 1948. Mr. Grant, who was until recently factory manager of the G.E.C. transformer works at Witton, was development design engineer in Marconi's high-power transmitter group from 1936 to 1946.

J. Cunningham-Sands, A.M.Brit.I.R.E., has left Rudman Darlington & Co., where he has been associated with the development and production of Reflectograph tape recorders, and has joined Multimusic, Ltd., the new Multicore subsidiary (see "News from the Industry"). This new company has acquired the patents, goodwill and trade marks in respect of tape recorders and reproducers from Rudman Darlington & Co. and Rudman Darlington (Electronics) and Mr. Cunningham-Sands will be technical manager of the Reflectograph Division of Multimusic.

G. M. Ettinger, M.Sc., has left the English Electric Company, where he has been since 1955, to become engineer-in-charge of the recently formed engineering group of Marconi Instruments which will be concerned with general and nucleonic research, semi-conductor applications and technical liaison with other research organizations. After obtaining his electrical engineering degree at London University, Mr. Ettinger was awarded a Fulbright Fellowship for post-graduate work at New York University and Columbia University, New York, and subsequently joined R.C.A.

G. M. ETTINGER.

E. G. ROWE (See "Honours").

Three new directors have been appointed to the board of the Decca Navigator Company: **Graham L. Coles,** who in 1946 joined the marine sales staff on leaving the Royal Navy and has been manager of the company's marine division since 1947; **George Hawker,** B.Sc., who joined the company's systems planning division on leaving the R.A.F. in 1946, becoming head of the division in 1950 and since 1951 has been commercial manager; and **Herbert C. Lambert,** chief accountant of the Decca group, who also becomes group controller.

S. J. H. Stevens, B.Sc.(Eng.), A.M.Brit.I.R.E., has been seconded for three years from the Ministry of Supply to SHAPE (Supreme Headquarters Allied Powers, Europe) where he will join the signals group and be concerned with forward scatter equipment. For the past seven or eight years he has been in the electronics production (air) section of the Ministry working on airborne communications. As mentioned elsewhere he has been elected to the council of Brit.I.R.E.

OBITUARY

Dr. Alexander Meissner died on January 3rd, aged 74. He was born in Vienna and educated there in electrical engineering and machine design. From 1907 he worked for the Telefunken company in the early development of quenched spark transmitters. He will, perhaps, be best remembered for the regenerative valve oscillator circuit which bears his name and which he developed from 1913 onwards. After 1930 he worked in the research department of AEG and his interests once again turned to heavy electrical engineering. He received many honours from universities and the learned societies.

Frederick George Creed, inventor of the Creed teleprinter, died on December 11th at the age of 86. Born in Nova Scotia, he came to this country in his late twenties, bringing with him the idea for his system of telegraphic printing.

HONOURS

Among the recipients of awards in the Queen's New Year Honours List were the following:—

William R. J. Cook, C.B., deputy director, Atomic Weapons Research Establishment, Aldermaston, who receives a knighthood.

Dr. Harry W. Melville, secretary, Department of Scientific and Industrial Research, who is appointed a Knight Commander of the Order of the Bath.

J. E. S. Cooper, C.M.G., assistant director, Government Communications Headquarters, becomes a C.B.

Major-General W. R. C. Penney, C.B., C.B.E., D.S.O., M.C., lately director, London Communications Security Agency, is promoted Knight Commander of the British Empire.

E. H. Ball, managing director, British Thomson-Houston; **V. A. M. Hunt,** director, Civil Aviation Control and Navigation Directorate, Ministry of Transport and Civil Aviation; **J. A. Mason,** M.M., manager and director, Automatic Telephone and Electric Co., and a director of British Telecommunication Research; **C. Metcalfe,** managing director, E.M.I. Electronics; **J. C. R. Proud,** O.B.E., director of broadcasting, Cyprus; and **M. J. L. Pulling,** O.B.E., controller, Television Service Engineering, B.B.C., are appointed C.B.E.

W. J. Challens, senior superintendent (weapons electronics), Atomic Weapons Research Establishment, Aldermaston; **Lt.-Col. E. N. Elford,** T.D., manager, radar division, Marconi's; **R. G. Fall,** senior signals officer, Civil Aviation Telecommunications Directorate, Ministry of Transport and Civil Aviation; **R. A. McMahon,** secretary, British Electrical and Allied Industries Research Association; **H. K. Robin,** chief engineer, Communications Department, Foreign Office; **E. G. Rowe,** chief valve engineer, Standard Telephones and Cables; and **Wing Cdr. E. M. Smith,** M.B.E., chief executive officer, Foreign Office, Government Communications Headquarters, become O.B.E.

T. D. Fookes, civil aviation communications officer, Air Traffic Control Centre, Uxbridge, Ministry of Transport and Civil Aviation; **J. A. Leith,** engineer-in-charge, B.B.C. Westerglen station; **D. W. Rae,** 1st radio officer and purser, s.s. *Pyrrhus*; and **J. O. C. Whelans,** production engineer, Mullard Radio Valve Company, are appointed M.B.E.

OUR AUTHORS

John Gray, B.Sc., M.I.E.E., who reports on the training of technicians in electronics in an article in this issue, was head of the engineering department at Paddington Technical College from the end of the war until being appointed to his present position as principal of the College of Electronics in the Royal Radar Establishment at Malvern. He graduated at London University in 1928 and after some time in industry went to the Borough Polytechnic, London, as senior lecturer in electrical engineering. During the war he was in the Royal Navy working on degaussing and allied problems.

H. J. F. Crabbe, who describes a folded corner horn in this issue, has been senior technician in the department of phonetics at University College, London, for three years. He is engaged in research on the analysis and synthesis of speech and allied acoustic subjects. Prior to joining the College he was for five years in the final inspection department of Decca Radar which he joined after national service spent in the R.E.M.E. working on anti-aircraft radar equipment.

J. C. Muller, B.Sc.(Eng.), author of the article on pulse-type frequency measurement on page 83, took a graduate apprentice course with the G.E.C. after obtaining his engineering degree at the University of Witwatersrand, Johannesburg, in December, 1955. He recently returned to South Africa to take up an appointment for the company in the Union.

Training Technicians in U.S.A.

THE PATTERN OF RADIO AND ELECTRONICS EDUCATION IN AMERICA

By JOHN GRAY*, B.Sc., M.I.E.E., A.M.I.Mech.E.

DURING a semi-private visit to the U.S.A. in the summer of 1957, advantage was taken of the opportunity to visit various firms and colleges specializing in electronic work. It is not claimed that the investigation was exhaustive, because only about six firms and six colleges were visited. These, however, were situated in such different and widely separated places as New York, Brooklyn, New Jersey, Washington D.C., Philadelphia, St. Louis, Chicago and Milwaukee. It is considered, therefore, that a fairly representative picture was obtained of the training facilities for electronics technicians.

General Education.—This follows the same general pattern as the English educational system between the ages of 5 and 18 years. Under the American system children attend primary schools up to about 10 years of age, then junior schools to 14 years and finally two or four years of high school. They may leave school at 16 years and take a job, but most of them stay up to 18 years of age. In these final two years there is opportunity for vocational training in the electrical or mechanical trades, or they may continue their general education in readiness for college. There is no 11+ exam. and no nation-wide examination similar to our General Certificate of Education, taken at 16.

The high schools maintain a fairly good standard. They have the usual terminal examinations, and the school leaving examination, which is taken at 18, is about equivalent to our G.C.E. Ordinary examination. Each school awards its own diploma.

Technical Education.—About one quarter of the boys leaving a technical high school at 18 go on to a college and study on a full-time 3-year course for a B.A. or B.S. degree.

The boys who have had the vocational training, between 16 and 18 years of age at the high school, may get a job in the appropriate trade and will be immediately useful. They may increase their technical knowledge by attending evening classes and by the time they are 21 they should have become skilled tradesmen.

For the more technical work in heating, refrigeration and air-conditioning, automobile repairs and, more particularly, radio and TV servicing or electronics, young men find it necessary to take an intensive day course of about 2 years' duration. Most of these young men, aged 18-22 years, have to do part-time jobs at local factories in order to support themselves and to pay their fees.

Many of the technical schools arrange attendance from 7 a.m. to 1 p.m. or from 2 p.m. to 8 p.m., so that students may put in a 5-day college week, amounting to 30 hours, and still work locally. Some evening classes are offered (7-9.30 p.m.)

None of the colleges visited was maintained by the local municipality or State. Some were private colleges run for profit but others were supported by large local firms or endowed and run on non-profit-making lines. Fees in the non-profit-making colleges were from $120 for an 18-months course, but in the private colleges some of the fees were as high as $1,200 for a similar course.

Radio and TV Servicemen's Course.—Most of the colleges offered an intensive 12-months course suitable for radio and TV Servicemen. The students spent most of this time on commercially made domestic receiver chassis, familiarizing themselves with the circuits and locating and rectifying faults with the aid of standard test equipment. Formal theory lectures were cut to a minimum and very little mathematics and physics was studied.

Junior Electronics Technicians' Course.—In the extended courses of 18-months duration, the technical principles were dealt with more fully, some calculation work was covered and lectures given on related topics in light and sound. Men qualifying from this course readily find posts as junior technicians on the installation and maintenance of electronic equipment in broadcasting or industry. The course is widened to include telecommunication transmitters and industrial electronic equipment.

Senior Electronics Technicians' Course.—At some of the better colleges, this course was of 24-months duration and embraced most of the application of electronics such as broadcast transmitters and receivers, radar and industrial equipment. A very thorough treatment of fundamentals was given including mathematics up to differential equations, and topics in physics related to electronics were similarly treated. A number of colleges were able to devote a small amount of time to engineering drawing, technical English and social studies.

Some of the colleges are authorized to award Associateships in Applied Science (Electronics) to successful students on this course. This award has the backing of State education authorities and is recognized by professional bodies and industrial firms. Men qualifying from this course will undoubtedly be able to fill posts as senior electronics technicians in telecommunications or industry.

At the Milwaukee School of Engineering, the students are able to take an initial 1-year course in electronics and then pass on to a 2-year course dealing with a wider variety of subjects, roughly equivalent to parts 1 and 2 of a British engineering degree course. A very thorough treatment of fundamentals was given. This school is authorized to award a Bachelor of Science (B.S.) degree to successful students. A 2-year day course was available as a 6- or 7-year evening course at the same overall cost.

Graduate and Post-Graduate Courses.—These must be considered to be outside the scope of the present investigation as none of the large universities such as the Californian Institute of Technology or M.I.T. was visited; but it happened to be convenient to call in at the Brooklyn Polytechnic where, in fact, very sound courses for B.S., M.S., and Ph.D. degrees were in operation.

Bell Telephone Laboratories had an interesting scheme for their new graduate employees. New

* College of Electronics, Royal Radar Establishment, Malvern.

graduates were appointed on full salary as junior engineers or scientific officers. In their first year, they could attend lectures on three days per week in post-graduate mathematics and physics and specialist courses on such topics as semiconductors, computers and control systems. Some of the lectures are given by visiting university lecturers, others by senior engineers of the Bell organisation. On the other two days of the week, graduates obtain practical experience in the research or development laboratories and spend a few months in each of a number of departments.

In their second year, they could continue to attend a few lectures but, by this time, they were expected to have shown an aptitude for the work in a particular department and were kept there to do a worthwhile job.

Conditions in Colleges. Most of the larger colleges had about 4,000 day students. About 50 per cent of these complete and pass the short 12-month elementary courses and about 25 per cent the more advanced 2-year courses.

The colleges are having a difficult time in their competition with industry for suitable men to act as lecturers or instructors. The lecturers are mostly university graduates, some with useful industrial experience, who can lecture on advanced fundamental theory and mathematics. The more elementary lectures are given by instructors who have extensive practical experience of electronic equipment and a fairly sound knowledge of underlying principles; these instructors also supervise in the laboratories. In the larger colleges, a member of the staff acts as student councillor or adviser. He spends all of his time watching the progress of individual students, advising them, and helping to place them, when qualified, in suitable posts.

There do not appear to be any nationally recognized salary scales for technical lecturers, and salaries and conditions of service seem to be a matter for direct negotiation between individual lecturers and the Principal or Director of the college.

Buildings. None of the technical colleges visited was controlled by the local municipality or state, and the type of buildings and equipment provided was influenced by the degree of local endowment.

Some of the smaller colleges are housed in converted shops or commercial premises but the larger and more prosperous ones have been able to have large new buildings. Most of the colleges were situated in built-up areas and none had the spacious grounds or campuses seen in American films.

Equipment. Most of the smaller colleges with a bias towards radio servicing made use of a large number of used radio and television receiver chassis with a reasonable amount of test equipment such as signal generators, multi-range meters and oscilloscopes.

Those colleges doing more fundamental work in advanced electronics make more use of "breadboard" circuits made up from components by some of the students and laboratory instructors. This was supplemented by adequate commercial test and measuring equipment.

The more prosperous colleges have spent large sums of money in elaborate commercial equipment such as complete sound and vision transmitters, and specialized industrial electronic equipment. Many of the colleges are using the special Philco electronic circuit demonstration equipment, but more thought might have been given to the devising of other special demonstration equipment to illustrate fundamental principles during lectures.

There was little equipment suitable for microwave experiments or to demonstrate auto-control or servo-mechanism principles, but it was understood that some of the colleges intended to set these up.

It seemed that more thought might have been given to the efficient planning of the layout and power supplies to the laboratories. The electrical machine labs, in particular, were rather old-fashioned compared with many British colleges.

Amenities. None of the colleges visited had hostels for resident students, but lists of suitable lodgings were kept and students directed to suitable accommodation. The larger colleges had canteens run on the self-service system, where students could get light refreshments from early breakfast to evening meals. Nearly all of the colleges had large pleasant common rooms and smaller club rooms. The students had organized themselves into Student Unions and various recreative clubs.

Practical Training. At the end of their 2-year electronics course successful students are able to get jobs, quite readily, as junior technicians in electronics firms. They acquire practical experience in the course of their routine work and if they vary their experience sufficiently they can become experienced senior technicians in the course of a few years.

None of the firms visited was running formal apprenticeships in electronics or undertaking the responsibility of a full training scheme. There was no part-time day release, but some firms would refund fees to junior employees who were successfully attending evening technical courses.

Some firms were running normal apprenticeship schemes on a small scale for toolroom craftsmen. Apprentices were recruited at 16 years of age and given initial practical instruction in a training bay in the main toolroom. Later, they work under experienced craftsmen in the main toolroom. During the 5-year apprenticeship, the apprentices are required to attend evenings classes in appropriate subjects at the nearest technical college and fees are refunded by the firm to successful students.

Conclusion.—The normal pattern for a young man wishing to train as an electronics technician appears to be as follows.

First, a general education in ordinary and technical high schools up to the age of 18. Second, a fairly arduous full-time two-year theoretical course of study on electronics at a technical institute. Third, a junior technician's post in a firm, in which he picks up practical experience on his routine work.

As the students have to pay their own way during that two-year course, they are very conscientious with their studies, but the nature of the arrangement must be a considerable strain on them, financially and otherwise.

They receive very little formal *practical training* before taking a job. This can hardly be as satisfactory as the British Apprenticeship scheme, whereby a young man receives a formal graded practical training in various aspects of electronics before he settles in a particular job.

The American system has its faults but, in spite of these, it is turning out large numbers of electronics technicians who are able to undertake high-grade work in industry.

DESIGN FOR A

Folded Corner Horn

By H. J. F. CRABBE

Low-frequency Unit with a Response Down to 40 c/s

WHENEVER audio enthusiasts get together, the subject of loudspeaker loading at low frequencies inevitably arises and the advantages of this, that and the other conflicting system are zealously proclaimed. Usually, however, the protagonists will unite in agreeing that an exponential horn provides the ideal method of loading a cone loudspeaker, but that the sheer physical size of the system makes it quite inapplicable to domestic conditions. Nevertheless, excellent aural results can be obtained from structures of quite moderate dimensions. It is the purpose of this article to describe the design and construction of such a practical corner-mounted bass horn to provide a smooth response at high efficiency down to 40 c/s when driven by an 8-in speaker.

Advantages of Horn Loading.—First it may be helpful to review briefly the reasons for the superiority of the horn as a method of loudspeaker loading. Considered as an acoustic power generator a cone loudspeaker has a complex source impedance which is primarily reactive, with a major inductive component (the cone mass) in series with a capacity (the suspension compliance). For an optimum transfer of power to take place, the load should consist of an acoustic resistance equal to the total acoustic reactance of the speaker. The impedance offered to a cone by an unrestricted volume of air is but a minute fraction of this optimum load; and in the simple case of a unit mounted in an infinite baffle the air load is not only very small but at low frequencies almost purely reactive. The problem is how to modify this low air impedance so as to present the speaker cone with the high resistance independent of frequency which is necessary for efficient working. The various types of vented enclosure usually provide loading which approaches the optimum at one frequency only, i.e., they are resonant. Within its pass band an exponential horn behaves like a simple acoustic transformer which converts the low resistance of the free air at its mouth into a high resistance at its throat, the smaller the throat the higher being the resistance. Thus, by choosing a suitable size of throat, it is possible to obtain the correct load for any speaker, thereby greatly increasing its efficiency as a transducer. This increase in the efficiency also means that the actual cone excursion required to produce a given sound level is vastly reduced by a horn, so that uneven distribution of flux in the gap and non-linear suspension of the cone will contribute much less distortion to the output. Another great advantage of horn loading is that it results in heavy damping of the cone movement and consequent elimination of resonances. Amplifiers with a low output impedance are used to facilitate magnetic damping, but this is only effective at low frequencies, and the many minor resonances resulting from cone break-up which are only loosely coupled to the voice coil can only be reduced acoustically by a horn.

Horn loading is worth while at all frequencies and a number of speakers using the principle are available at reasonable cost for use at high and middle frequencies. However, the clarity and naturalness of the reproduction from these and push-pull electrostatic units are such as to underline the mediocre quality of most conventional bass reproducers. In the author's opinion a good bass horn of low cost which can be constructed by anyone with reasonable ability and enthusiasm would help to fill this gap. The problems involved in designing such a horn will now be considered.

There are three basic dimensions which must be

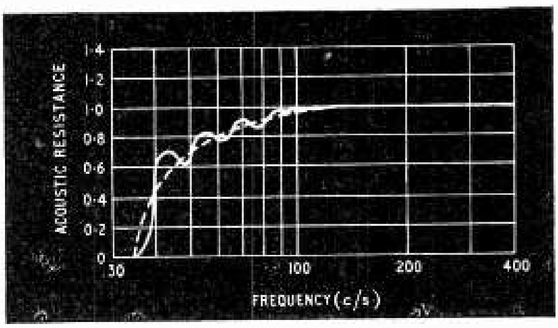


Fig. 1. Change of relative acoustic resistance with frequency at the throat of an ideal exponential horn (dotted line), and the same horn terminated at a mouth diameter of λ/3 (full line). The flare cut-off frequency is 35 c/s and the throat diameter 3 in.

established before a specification can be made for any horn. These are:—

(1) The rate of flare, i.e. the rate at which the cross-sectional area changes with distance along the horn axis.

(2) The area of the mouth.

(3) The area of the throat.

For a given rate of flare, (2) and (3) will automatically determine the length. Each of these factors will be considered in turn before proceeding to the practical design.

Rate of Flare.—In addition to having the characteristics of a transformer, an ideal exponential horn behaves like a high pass filter, and the throat acoustical resistance into which the speaker looks takes the form shown by the dotted line in Fig. 1. The frequency at which the resistance has fallen to zero is the flare cut-off frequency (f_{co}), which depends on the rate of flare (the more gradual the rate, the lower the cut-off). It is obviously necessary to arrange that this comes below the lowest frequency the horn is required to handle, and it may be assumed that this latter is 40 c/s as only the very deepest organ

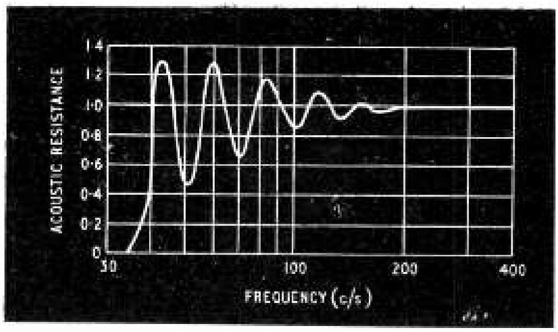


Fig. 2. Throat resistance of the horn of Fig. 1 when terminated at a mouth diameter of $\lambda/5$ (6.4 ft).

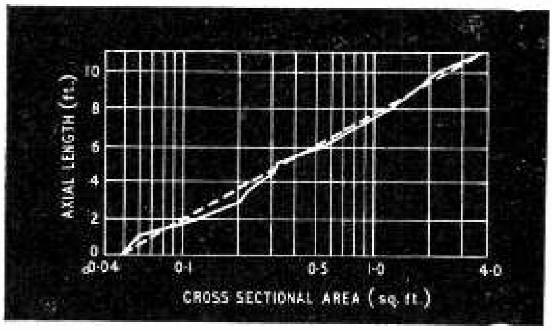


Fig. 3. Law of the proposed horn presented graphically. The ideal expansion (dotted) line may be compared with that of the practical shape (full line).

pedal notes are likely to have any significant energy content below this. To achieve a sufficiently constant load on the speaker down to 40 c/s a cut-off frequency of 35 c/s is suitable. The rate of flare (α) can now be determined from the equation $\alpha = 4\pi f_{co}/c$ where c is the velocity of sound in air. This gives $\alpha = 0.4$ per ft.

Mouth Area.—The second major factor influencing the low frequency response of a horn is the degree of mismatch of acoustical impedance as the sound passes from the horn mouth into free air. Such a mismatch causes reflections back into the horn, and the resulting resonant modes create irregularities in the throat resistance. For the curve of Fig. 1 to remain completely unaffected, the horn mouth diameter[1] would have to be $4\lambda/\pi$, where λ is the wavelength at f_{co}. However, Olson[2] has shown that this ideal condition is almost fulfilled if the diameter is reduced to $\lambda/3$, and has confirmed this by measurements on an actual horn, the results of which may be compared with the ideal curve in Fig. 1. In practice, for low frequency horns, the mouth diameter may be even further reduced to $\lambda/5$, which for a cut-off at 35 c/s is 6.4 ft, corresponding to a mouth area of 32 sq ft. The resulting throat resistance curve (Fig. 2) looks rather alarming, but the maximum variation of acoustic resistance is only 3 to 1, and Olson[3] has shown that irregularities of 6 to 1 will cause variations of power output of only 2 dB down to just above the cut-off frequency, provided that the throat is properly matched to the driving unit.

The horn so far envisaged will radiate effectively down to 40 c/s into a solid angle of 4π, i.e., free space. A reduction of the solid angle into which the horn is required to radiate will raise the acoustic radiation resistance immediately in front of the horn mouth, and the area of the latter must be reduced in proportion to retain the original matching conditions. Taking a practical case, if the angle in front of the horn mouth is $\pi/2$ or an eighth of a sphere, then the 32 sq ft mouth area may be divided by 8 without adverse effects. In the corner of a room at floor level the solid angle is in fact an eighth of a sphere, so that a horn placed in such a position will work satisfactorily with a mouth area of 4 sq ft. The room walls should extend in an unbroken manner for several feet beyond the horn mouth, otherwise the effective solid angle in front of the assembly may be more than the eighth of a sphere mentioned above.

Throat Area.—The cross-sectional area of the throat depends on the size and type of speaker drive unit to which the horn will be coupled. In general, from the point of view of economy and the availability of speakers suitable for horn loading, an 8-in unit is probably the most satisfactory. As a rough empirical rule for speakers with light paper type cones, it has been found that optimum matching occurs when the throat area of the horn is equal to one quarter of the piston area of the cone. A nominal 8-in speaker usually has an effective diameter of 6 in, which gives a throat area of 7 sq in or 0.049 sq ft.

Specification.—The final theoretical specification for the horn may now be formulated.

(1) Rate of flare $\alpha = 0.4$ (per ft).
(2) Area of mouth $A_x = 4$ sq ft.
(3) Area of throat $A_t = 0.049$ sq. ft.

The length of the horn x can now be determined from the exponential horn equation $A_x = A_t e^{\alpha x}$. This gives $x = 11$ ft. The resulting flare is represented graphically in Fig. 3.

Folding the Horn.—In folding the horn so that

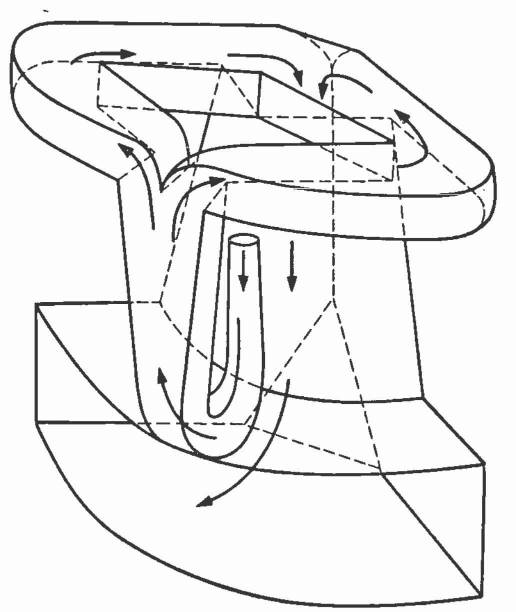
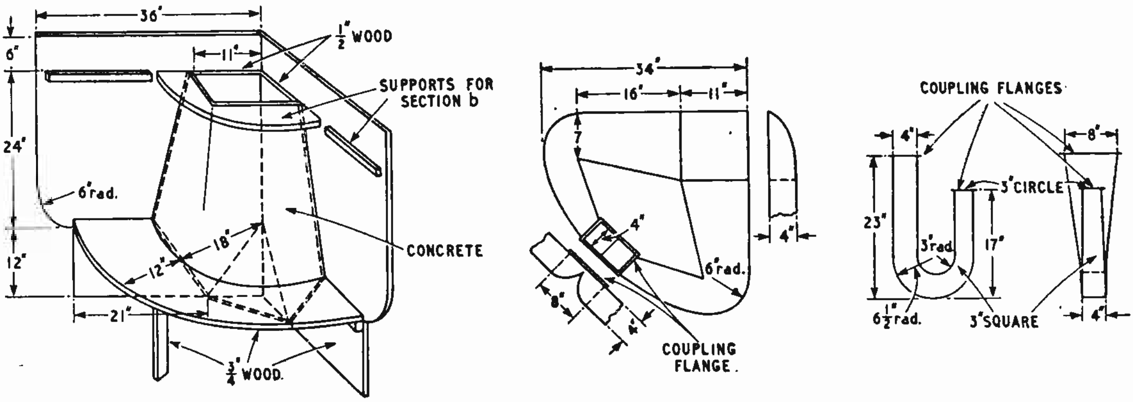


Fig. 4. Shape of the practical folded horn, showing the sound path from the small circular throat to the large quadrant shaped mouth.



(a) (b) (c)

Fig. 5. (a) View of the main frame of the horn to which the final vertical section and the mouth are permanently fixed. (b) An under side view of the middle part, showing the square opening which feeds into the vertical section, and the small rectangular opening which couples to the "J"-shaped section. (c) Two views of the "J", or throat, section.

it will stand conveniently in the corner of a room the following four requirements must be borne in mind.

(1) The mouth must be at floor level and should extend through 90° from one wall to the other to ensure proper matching into the room.

(2) The throat must be positioned so that the back of the speaker unit may be easily coupled to it, leaving the front of the cone free to radiate into the room at middle and high frequencies either directly or via a short horn.

(3) The horn must be folded sufficiently to avoid an excess of waste space in the total structure.

(4) The number of bends must be restricted to the absolute minimum in order to have the advantages of horn loading well into the region where the maximum energy levels occur in orchestral music, i.e., 200 to 500 c/s. This restriction arises because the wavefront travelling through a folded horn becomes bent in such a manner that, above a certain frequency, out-of-phase cancellation effects take place, and the response tails off in an erratic manner.

Requirements (1) and (2) are basic and determine the overall structure; whereas (3) and (4) conflict and a compromise solution is necessary. With the above factors in mind, a practical shape has been evolved (Fig. 4) whose expansion law approximates reasonably to the theoretical flare, as will be seen from a comparison of the two in Fig. 3.

Method of Construction.—To construct such a horn with sufficient mass and rigidity to avoid vibration and mechanical resonance is a difficult problem. After consideration of numerous alternatives, it was finally decided to use half-inch thick concrete for most of the structure; and only employ wood or composition board near the mouth where the acoustic pressures are relatively low.

The horn divides conveniently into three sections which may be taken apart for transportation; the details of the structure are shown in Fig. 5. It will be noticed that the bottom surface of the mouth is not included as this is provided by the floor of the room in which the horn stands. The detachable sections (b) and (c) are assembled by bolting together the drilled metal coupling flanges. Some sort of permanent mould or reinforcement is necessary for the hollow concrete sections, and it is convenient to make this of 26 s.w.g. tinplate which can be easily cut, bent and soldered. This tinplate constitutes the inner surface of the horn, and all the dimensions of the concrete parts given in Fig. 5 are for the tinplate shapes. To ensure that the concrete keys firmly on to the metal, strips of perforated zinc to protrude $\frac{3}{8}$ in are soldered on to the surface in a zig-zag fashion so that no point on the tinplate surface is more than 2 in from a place which will be firmly anchored into the concrete.

For anyone not a skilled plasterer the task of applying an even layer of concrete half an inch thick to the somewhat odd shapes requires a great deal of patience, and has to be done in easy stages. A mixture of one part of cement to three of sand is suitable. The sections should be left for several days to dry out thoroughly. The tiny cracks which appear must all be filled before the horn is assembled. Should the concreting process prove too tiresome, a little light relief is permissible on the final vertical section of the horn attached to the main frame, where a 1-in thick sand-filled panel made with hardboard bent to the required shape is adequate.

Assembling The Horn.—The main frame should be fixed firmly into position, and strips of felt stuck on the horizontal supports for section (b) (Fig. 5). This latter is then hoisted into position. It will be found that its centre gravity lies in front of these supports so that its weight is only completely held when the J-shaped section (c) is finally in position.

The inevitable inaccuracies of the parts make a certain amount of padding and packing necessary in the assembly process, but this may be left to the individual ingenuity. Where the three concrete sections join it is essential to seal completely the cracks with a filler, as quite minor leaks will drastically upset the performance at low frequencies. For constructors with young children, Plasticine will no doubt be readily available, and is very suitable for this operation. Finally, the front of the horn should be boarded up as in Fig. 6 to make the transition from mouth to room less sudden and consequently improve the matching. When this boarding up is done the resulting cavity around

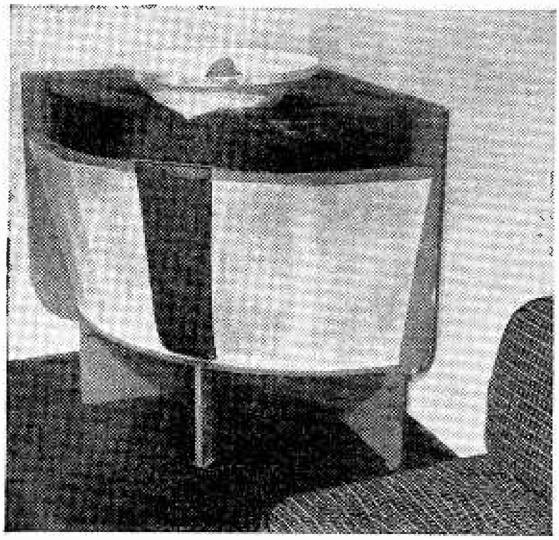


Fig. 6. The author's completed system with its decorative cover removed.

the J section must be stuffed with acoustically absorbent material to prevent it ringing. Screwed up newspapers tightly packed are very suitable for this purpose.

Choice of Loudspeaker.—It will be found that the horn enhances the low frequency efficiency of an 8-in speaker so greatly that if one unit is used to cover the whole range the balance may be upset in favour of the bass. Therefore in many cases the best approach would be to use a separate unit (preferably horn loaded) for the middle and high frequencies, and any moderately good 8-in unit in the horn for the bass. A little intelligent juggling with the cross-over component values and speaker impedances should equalize the efficiencies. The four-to-one ratio of cone to throat area mentioned earlier is relevant to a light cone of the type found on the average 8-in unit; the heavy cones fitted to many bass reproducers require a larger ratio for optimum matching, and because of this a 10-in or 12-in speaker of this type would be as suitable as a normal 8-in unit. In either case the speaker should have a fairly rigid cone without graded compliances, and the edge suspension should be sufficiently free to ensure a low resonant frequency, say below 50 c/s.

Another alternative (adopted by the author) is to use a single very high flux twin cone unit of a type designed specifically for horn loading; and to balance the low frequency efficiency provided by the main horn, at middle frequencies by means of a short straight horn (described later) coupled to the front of the speaker; and at high frequencies by the increase in the radiation from the small inner cone. Although such a speaker is expensive, the cost should be compared with that of two medium-priced units and a cross-over network. The end of the short middle-frequency horn may be seen in Fig. 6.

Fitting the Speaker.—As has been mentioned earlier, the low-frequency horn will not transmit sound effectively above a certain frequency because of the folds in its length. In this case the angle of the bend nearest the mouth is 90°; and the criterion is that when the diameter of the horn at this bend is equal to $\lambda/2$ the first dip in the response will occur[4]. The effective diameter at the final bend is approximately 1.4 ft, which means that a dip will occur at about 400 c/s. The coupling between the speaker and horn throat should therefore be designed so that the energy transmitted through the horn falls away rapidly above, say, 350 c/s. This is achieved by placing a cavity between the cone and throat which acts as an acoustic capacitance, and shunts the horn resistance above the chosen frequency. In addition, this cavity removes the mechanical restriction on the cone movement imposed by the low frequency horn throat resistance, and allows the short horn on the front of the cone to take over efficiently at middle frequencies. This arrangement provides an acoustic equivalent of a conventional cross-over circuit.

The volume of the cavity must be such that its acoustical reactance equals the acoustical resistance of the horn throat at 350 c/s. Within its pass band the throat resistance of an exponential horn is $\rho c/A_t$ where ρ, c and A_t are the density of air, the velocity of sound, and the cross-sectional area of the throat respectively. The reactance of an acoustical volume capacitance is $\frac{c^2}{2\pi f V}$, where V is the volume and f the frequency. This gives

$$\frac{42}{45.2} = \frac{1.43\times 10^6}{700\pi V},$$

where V is in c.c.

Therefore V = 700 c.c. or 42.6 cu in.

On many 8-in. speakers the volume of air between the rear of the cone and the frame is approximately 40 cu in; and with these the simplest method of coupling to the horn is to seal off this cavity, leaving one opening suitably placed for fixing to the horn throat. Whatever arrangement is used it is essential that any extension to the throat should maintain the cross-sectional area of 7 sq in right up to the cavity. The author has found that if the point of entry of the throat into the cavity is placed asymmetrically with respect to the speaker axis, the cavity tends to behave like a Helmholtz resonator, and produce audible coloration of the output. The way to overcome this is to couple the throat coaxially as in Fig. 7.

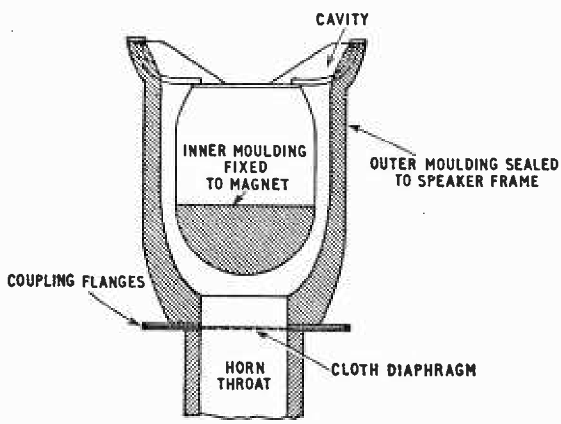


Fig. 7. Sectional view of the speaker mounting showing the method of extending the horn throat area up to the cavity at the rear of the cone.

The dimensions of the moulding on and around the magnet will obviously depend on the individual speaker unit, but shapes of this sort can easily be made with plaster of Paris, and set quickly in removable cardboard moulds.

Despite the attenuating effect of the cavity, a certain amount of high frequency energy will still travel through the horn and may colour the output. As a final precaution against this, a further low pass filter may be added in the form of a cloth diaphragm at the throat. The fitting of this is not critical, and it has been determined experimentally during listening tests that two layers of medium thickness woolly cloth material are sufficient to remove all audible effects. The position of the diaphragm is shown in Fig. 7.

When the resulting speaker-plus-coupling unit is fitted to the horn, it will be found that the speaker cone lies several inches below the top of the middle concrete section. This is deliberate as the space is used to accommodate the throat end of a short middle-frequency horn, thus reducing the overall height of the final assembly. If the second horn is not fitted, the speaker should be mounted flush with the top of the structure and the main horn throat extended upwards appropriately. It is not necessary to continue the flare taper when this is done, as this would not cause the cross-sectional area to change very much in a few inches.

The upward facing arrangement of the cone causes a wide dispersion of sound at middle frequencies which is very pleasing when reproducing orchestral music. The attenuation, which would otherwise be suffered by very high frequencies through being beamed straight up at the ceiling, should be avoided by fixing a small elliptical metal plate above the cone to reflect the beam back into the corner of the room, from where it will be reflected forwards in a more horizontal plane (see Fig. 8). The back of this reflector can be coated with Plasticine to avoid any possibility of ringing.

Middle-Frequency Horn.—To achieve a satisfactory performance, a middle or high-frequency horn must approach the ideal much more closely than one for low frequencies only. This means in practice that it must have a straight axis, and its mouth diameter must be at least $\lambda/3$ at the cut-off frequency. Failure to fulfil this last requirement is the primary cause of the coloration for which some horn loudspeakers have a reputation.

The cut-off frequency of the short horn must be chosen so that it begins to load the front of the speaker cone just as the rear cavity starts to shunt the throat resistance of the main horn. In the absence of the short horn the output from the bass horn begins to fall above 330 c/s, so an f_{co} of 325 c/s seems about right for the small horn. Using the equation given earlier this gives a rate of flare (α) of 0.304 per in.

Ideally, the throat area of the short horn should be smaller than the cone area as in the main horn. However, with an 8-in speaker, it is then almost impossible to devise a form of coupling which will distribute the load evenly over the cone area and at the same time avoid irregularities of response due to path length differences and cone break-up. In practice it is sufficient to make the throat area equal to the piston area of the cone. This is quite an efficient arrangement at middle frequencies, because, even in the absence of a horn, when the cone is an appreciable fraction of a wavelength in diameter, the resistive component of the air load becomes predominant. With a horn, acoustic damping of the cone movement is also provided.

To avoid standing wave effects between parallel surfaces, it is preferable to make the horn with a circular rather than rectangular cross-section. A mouth diameter of 14 in corresponds to $\lambda/3$ and is probably adequate, but the author has gone to 22 in to be completely safe. This results in an axial length of 8 in, the first 5 in of which is accommodated below the top of the main assembly. Fig. 8 shows the sort of arrangement required; the end of the short horn may be seen in the photograph (Fig. 6).

The horn can easily be made by sticking together a succession of cardboard cones of appropriate angle and coating the resultant shape with approximately one inch of plaster of Paris. The shape at the throat will depend on the speaker unit, but should be arranged to come within ⅛ in of the cone, and to stand securely without leakage on the speaker

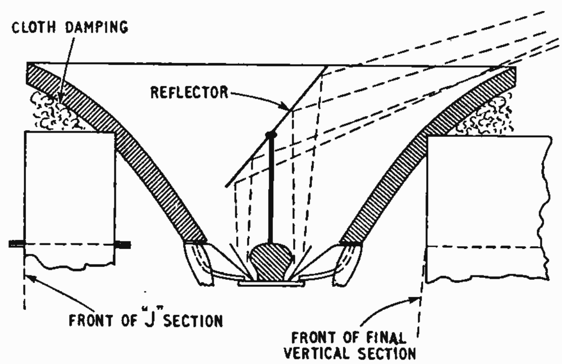


Fig. 8. Sectional view of the short middle-frequency horn showing its relation to the cone and main horn structure. The position and angle of the metal reflector are also shown.

frame under its own weight. The china-like quality of the plaster and the annular shape of the horn mouth combine to produce a slight mechanical resonance, so that the topmost few inches of the horn should be bound on the outside with cloth or rope to prevent ringing.

The central "bung" attached to the magnet pole in Fig. 8 is an attempt to achieve some degree of horn loading on the apex of the cone from which the very highest frequencies are radiated. It is shaped so that the area between it and the inner cone expands exponentially. This refinement is now fitted by the manufacturers of the unit used by the author.

Frequency Response.—Objective measurements of the performance of any loudspeaker are bound to be very difficult under domestic conditions. This applies particularly to the frequency response which can be completely distorted by room acoustics. Since the present speaker must by definition stand in a corner, the use of an anechoic chamber for measurements is out of the question. Fortunately the room in which the author's model stands is of irregular shape, has a varying ceiling height, and most of the walls are of the plaster partition variety, all of which results in a very marked lack of reverberation at low frequencies. In these circumstances a subjective assessment of the frequency response is not completely valueless. With a constant input from a low impedance amplifier source, the radiation from the main horn mouth extends smoothly with no audible peaks or dips from 300 to 40 c/s, below which it falls away rapidly. Above 300 c/s the short horn progressively takes over with no change of level or quality in the total output, the frequency at which the sound is divided equally between the two being 330 c/s. It is impossible to detect any frequency doubling at 40 c/s even at very high input levels.

With the short horn removed, the cross-over frequency changes to 370 c/s and is less sharply defined. The efficiency in the 500 to 1,000 c/s region is also somewhat lower.

Damping.—Next to the increase of efficiency the most noticeable effect of horn loading on a cone speaker is the virtual removal of the major cone resonance, and this change can be most dramatic. Units which have an impossibly boomy and coloured bass response in more conventional enclosures give a very good account of themselves in this horn. As an extreme example a "cheap and nasty" speaker with the major resonance at 250 c/s was coupled directly to the horn throat. Despite the unity ratio of cone to throat area and the consequent mismatch, the resulting bass was smoother than much that passes for "hi-fi" elsewhere. Moir[5] has demonstrated the deleterious effect on amplifier performance of a load which varies widely with frequency, and has shown that the damping of the cone resonance afforded by a horn is accompanied by a corrresponding flattening of the electrical impedance curve. Fig. 9 shows the impedance characteristics of two speakers in the horn and unmounted. It will be seen that when the resonance occurs well within the pass band of the horn it is damped completely out of existence, and when it is below the horn cut-off it is reduced in both amplitude and frequency.

A basic criterion for high acoustic damping in any loudspeaker system is that its transient response shall be independent of the source impedance feeding it. One very simple test for checking this is alternately to short and unshort a 1½-V cell across the speaker coil. This applies step functions alternately at very low and at infinite impedance respectively, and the resulting click sounds should be indistinguishable from one another. They are in fact identical with this speaker.

Efficiency.—In the absence of proper measuring facilities one can only guess at the overall electro-acoustic efficiency of the system. As a first step the peak electrical power fed into the speaker was measured when reproducing orchestral music. The method recently suggested by Baxandall[6] was used, and the sound level at times was very high indeed. The peak power reached was ½ watt, and that only very rarely. The vast majority of very loud climaxes did not exceed ¼ watt, and for most music most of the time a 100 mW peak power was adequate for realistic reproduction. Hopkins and Stryker[7] have developed a method of relating the subjective loudness needs of the listener to the maximum amplifier power required, for speakers of various efficiencies in rooms of various sizes. Their table shows that for realistic reproduction of a 75-piece orchestra in a room

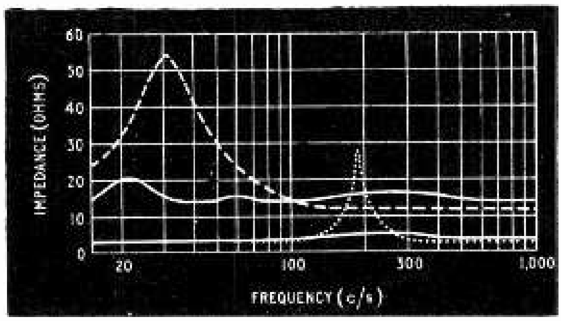


Fig. 9. Electrical impedance curves of two speakers, in the horn (full lines) and unmounted (dotted lines).

of 1,500 cu ft a maximum power of ¼ watt corresponds to a speaker efficiency of 40%. This seems about right in view of the high flux drive unit used. With more moderately priced speakers it should still be possible to achieve low frequency efficiencies of up to 15%, which would mean very modest amplifier requirements for domestic use. Indeed, economies in this direction could more than cover the cost of building the horn.

Subjective Listening Tests.—The final judgment of the quality of any loudspeaker system must be the subjective one of music-lovers, and numerous members of this species have listened to the horn described in this article. Attention has been directed to the low frequencies which are a function of the horn, rather than the high frequencies which depend on the type of drive unit used.

The general view seems to be that the bass is smooth and clean with a complete absence of coloration or resonance, transients are very clear, and when the full orchestra is playing a loud passage all the low frequency detail is preserved. The reproduction has an exceptionally solid and firm sound. There is great depth in the bass only when there should be. The sort of deep and impressive " glow " added by some speakers whenever the music is loud (possibly caused by excitation of the major cone resonance) is not a characteristic of this system; neither is it a characteristic of an orchestra in the concert hall.

Possibly the most important single requirement of a speaker is that discriminating listeners can live with it. The author has lived with his with increasing satisfaction for over a year, a test which numerous previous set-ups have failed to pass.

Finally the author would like to acknowledge the invaluable help of J. E. West and R. H. Clayton in designing the folded horn shape, and to mention that they have also constructed prototype models with equal success.

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U.H.F. IN U.S.A.

HOW ONE SERVICEMAN CONTRIVED TO STAY HAPPY ON THE HIGH BANDS

By *JACK DARR**

SOME little time ago, the Powers That Be in Washington got together for a potlatch, an indaba, a punchayet and a pow-wow, (with apologies to Rudyard K.) and decided that the TV men were having much too easy a time of it.

"What could we do to stir 'em up a bit?" asked one. "They're getting fat and lazy, and making entirely too much money!"

"Indeed," agreed another of the patriarchs. "Why, if you'd seen what that man charged me last week for only —."

"Gentlemen!" rumbled the Chair, frowning. "We mustn't let personal feelings enter into this! The problem before this Committee at present is co-channel interference, lack of available channels, and overcrowding in general. Do I hear any suggestions?"

"If I had my way," said one member, "I'd assign a u.h.f. band, say from 470 to 890 megacycles to TV broadcasting."

"Ah, yes," smiled the Chair, "that might solve *all* of our problems. Not only shall we have given the broadcasters more lebensraum, but we shall have taken a good wipe at some of those servicemen. When I think of all the trouble they're going to have I just want to —." At this point, the Chair became quite overcome with joy, and was led off, still chortling, to apply restoratives.

The preceding fabulous version may suffer from a certain lack of verisimilitude, but in one form or another some such vision must have arisen in the minds of the American TV men when they first encountered this new band of frequencies.

These were known as the Ultra High Frequency channels, although different versions have been circulated: one disgruntled technician, after hours of probing a roof for a non-existent signal, claimed they stood for "Up Here Forever," while another, attempting to get sufficient signal a few miles away from the station, held out for "Unusable Here in Fringe." There have been others, but this must pass through the mails!

Technical difficulties abounded in the early days of u.h.f. transmissions, not only among the receiving gentry, but among the transmitting types as well. The nation's first u.h.f. station, in Portland, Oregon, ran headlong into some of these: although reception of the signals was excellent a few miles out, not a set in the city proper could receive the station! Investigation revealed that the transmitting antenna partook of some of the characteristics of a lawn-sprinkler: the signal was being "squirted" well out into the outskirts, but the area immediately surrounding the "sprinkler" was quite dry! (This was finally remedied by tilting the antenna, so as to bring the signals down into the city itself!)

Propagation Characteristics of U.H.F. Signals.—As in v.h.f. broadcasting, many of the tightly held pre-conceived notions about the nature of the signal path, line-of-sight transmissions, and so forth, were proved to be slightly in error, after a few months of field testing. With the much higher frequencies, it was assumed that reception would be truly line-of-sight, with no bending at all, and it was feared that there would be great difficulties with reflections and ghosts.

Practical experience has proved some of these assumptions true, some false. As in v.h.f. work, the "line-of-sight fallacy" has proven to be just that. Many instances of good reception in "impossible locations" have confirmed this, as will be discussed later. Ghosts and reflections are no problem; in fact, many technicians say that they are much less than at v.h.f.

Field Test Results.—A series of field tests made in primary, secondary and fringe areas brought forth some rather interesting results. The same antenna, a bow-tie with reflector, was used in all tests, together with an adjustable tower, to permit checking the actual field strengths at different heights. A field-strength meter was used in conjunction with a portable TV receiver, to check both picture quality and actual signal strength. To make the tests as accurate as possible, the same length of lead-in was used on all tests: the surplus was held away from the tower, off the ground, with a bit of dry string, thus making transmission line losses equal for all positions.

Several peculiarities were found during these tests, although not as many as had been anticipated. Several were made in places where local technicians had been complaining loudly of insufficient signal strength; these revealed that the major difficulty had been lack of antenna *height*, coupled with the use of improper antennæ, with too little gain. Most of these locations were from 40 to 50 miles away from the station, with a great deal of this distance being over water. This brought out two things: (1) that the outer edges of the fringe were much farther away than had been previously thought possible, and (2) that over-water transmissions suffered much less loss than a corresponding distance over land. One novel discovery resulted from tests at a medium distance location, where a fairly strong signal was expected, and a quite weak one received; checking the map disclosed a very large swamp exactly between transmitter and receiver, which led inevitably to the conclusion that the signal, like the famous "Chloe," had gotten lost in the swamp!

The presence of very tall trees between receiver and station also leads to trouble. It was found necessary in all cases to go above trees to get reliable signals. This in contravention to common experience with v.h.f., which suffers very little from

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"foliage attenuation." Even a large grove of pines, with their fine needles, caused quite a loss. Another source of excessive attenuation in the signal path was the presence of thickly populated areas, tall buildings, etc. Added antenna height was needed here.

Summing up, it may be said that no more difficulties were encountered than in v.h.f. work: provided, of course, that the proper antenna and other equipment are used, along with proper installation techniques. Distances worked were far in excess of those predicted, even by the most enthusiastic proponents of u.h.f. broadcasting.

U.H.F. Receiving Aerials.—Receiving antennæ for u.h.f. work are, of course, built to the same theoretical designs as those used by their big brothers on v.h.f. Many types are found in both "sizes," such as the multi-element Yagi, used in u.h.f. work up to 12 elements, the dipole and reflector, which appears in many shapes. The most common of these is the "bow-tie," so called for obvious reasons. These are quite realistic imitations of that popular article of apparel, and gave rise to much crude humour, the object of which was usually the distributor's salesman, if he walked into a shop wearing a large bow-tie (real), to be greeted with "What channel is *that* on, for goodness' sake?"

In other configurations, the dipoles become large tubes, up to 3 inches in diameter, conventional ½-inch elements, and many others; however, they remain basically dipoles. The conical makes its appearance, in sizes appropriate to the high frequency; it is used with a reflector screen, as are almost all of the others.

All of these types are occasionally used "stacked." The minute dimensions of the antennæ makes possible the stacking of 2, 4 or even 8 antennæ practicable, at least in so far as physical size is concerned. The increase in efficiency is the same as on v.h.f.

One popular type makes use of 8 dipole and reflector combinations, with a large curtain reflector. It is a smaller duplicate of the arrays used on v.h.f., known among technicians as the "flying bedsprings," not too popular because of its weight and wind-resistance. On u.h.f., this whole antenna is less than four feet square!

Vertical stacks of Yagis, conicals, and bow-ties are common, often up to 4-bays. The corner-reflector, a quite efficient type, uses bow-ties, dipoles, and even conical elements, and is also small enough to be practical.

One unusual antenna type seen, though not too often, is the helix. This antenna, developed from a prototype used in radar work, inevitably became known as the "flying corkscrew"!

Design Features of U.H.F. Aerials.—Because of the extremely high attenution offered to a u.h.f. signal from practically everything, u.h.f. antennæ are built somewhat differently from their big brothers. Instead of the common types of insulators, across the antenna terminals, complete isolation is achieved by supporting the antenna elements at a null point with heavier insulators. This is possible because of the rigidity of the small elements, and gives very good protection against losses across the antenna terminals from accumulations of dirt and moisture.

On other types a "delta-match" is achieved by fastening the dipole itself directly to the boom, and attaching the lead-in at a point far enough out on each element (which is usually a straight, instead of folded, dipole), to achieve a correct impedance match with the 300-ohm lead-in. This eliminates the need for any insulators at all, and causes a great deal of confusion among the less-informed technicians. One of the brethren recently shipped a batch of antennæ back to his distributor, with the complaint that the maker had entirely forgotten to install the insulators!

Lead-in, "Hardware" and Accessories.—Because of the very high frequencies, losses are very high in the lead-in and other materials. This has brought about the development of special types of lead-in wire for u.h.f. work. The first type used was the open-wire line, with solid conductors held apart by small rods of polystyrene. This is a very low-loss type, and is still used in many installations.

Moisture accumulation on the line is fatal to the feeble u.h.f. signal; with conventional flat-ribbon line the difference between wet and dry loss at u.h.f. is tremendous; so much so as to make the line entirely unsuitable for this service. The air-insulation of the open-wire line makes it the best of its kind, but it is undoubtedly quite difficult to handle and install (an understatement).

Later on, a special u.h.f. lead-in was brought out, to reduce the "wet-loss." This was a poly-insulated line, with a tubular web instead of the common flat web; the purpose of this was to confine the signal-carrying fields entirely within the dry space inside the line.

Installation of this line required special techniques: chief among these was the need for bringing the line "up and over" at the antenna, instead of directly up from below. This brought the open end of the tubular line facing downward, and was supposed to aid in preventing rain from entering the line. Of course, in addition to this precaution, one is supposed to plug and tape the upper end of the line.

One TV viewer had these facts of u.h.f. life rather forcibly brought home. This chap, a chronic "do-it-yourselfer," had installed his own antenna. One rainy night, peacefully watching the set, he was annoyed by the unmistakable "plop" of dripping water. A search of the house failed to turn up any leaks in the roof, and he returned to the TV set just in time to be greeted by several expensive noises, accompanied by a tinkle of falling glass, a dark screen, a puddle of water beneath the set, and a decided odour of burnt insulation!

Investigation (by a technician) disclosed that the u.h.f. lead-in he had installed made a direct line from the antenna, down through the top of a window to the back of the set. The hollow line was giving a beautiful imitation of a watering hose, liberally sprinkling the TV set's innards! The cold water falling on the hot chassis had caused the breakage of several valves, including the line-scan output, e.h.t. rectifier, damper, etc. The dissolution of these vital parts had led to the destruction of the line-scanning transformer and some other miscellaneous hardware.

Properly installed, this line will give no trouble. If the downlead is turned over and properly sealed at the top, including a good wrap with plastic tape

(*Continued on page* 65)

and a spray of acrylic plastic, it will not pick up moisture from this end. The line should be brought down the side of the house and turned up again, where it enters the house, to provide a "drip-loop." At the very bottom of this loop, two nicks with the side-cutters will make a drain-hole, to allow the moisture which inevitably condenses inside the line to escape. The only other alternative would be the complete hermetic sealing of the line, or pressurizing it, either of which is technically possible but economically impractical.

A still later development in u.h.f. lead-in brought forth the "foam-line," identical in structure to the hollow line, but with the space filled with "foamed" polyethylene. A more economical type of line is the "perforated" type of 300-ohm ribbon. This is merely standard ribbon line, which has had most of the web removed in long slots by a special punch. Thus it approaches the open-wire line, as far as air-dielectric goes, and is much cheaper than any of the others. Moisture, from rain or heavy dew, will cause a momentary loss of signal, but not as much as in the standard 300-ohm line, and the attenuation will soon be lessened, as the moisture dries or drips off. Its ease of installation and economy have made it probably the most popular among technicians.

A few other points deserve mention before we leave the subject of lead-in for u.h.f. No longer can sloppy methods of installation be tolerated. At these frequencies the line must be tight and firmly held, and stand-offs must be as long as possible, to reduce capacity effects to nearby objects (not necessarily metallic objects, either!). If possible, the stand-off should be of the type which does not surround the lead-in with a metal ring, but the type which holds the line in a plastic, as far away from the metal as possible.

When going over gutters, or past downspouts, plumbing, etc., the line must be kept as far as possible from them. Making the turn over the eaves requires the use of several stand-offs, in order to make the line curve gently, instead of making a sharp bend. Just like the traditional Chinese demon, u.h.f. signals like to travel in a straight line. They must be gently coaxed into turning the corner; too sharp a bend, and they will hop off into space and go their merry way!

Installation: Probing for Signal.—In addition to the desirable practices outlined above, a few others might be brought out, as applied to u.h.f. installation. Over the past few years, the v.h.f. technicians have learned their own areas and can tell just what antenna, what height mast, etc., are needed to get a satisfactory picture. This is not always the case in u.h.f. areas. A great deal more probing of antenna locations is necessary, and there is never the certainty that any given antenna, installed at a given height, will pick up a good picture! Fortunately for the weary technician, the u.h.f. antennæ are so small that probing is quite easy; a bow-tie, mounted on a 10-15 foot aluminium mast will serve admirably.

The use of a field-strength meter is essential: the standard makes of meters, using turret tuners, would be easiest to convert to u.h.f. One of the coils for an unused channel is removed and a special u.h.f. converter stage, employing a crystal mixer, is slipped into its place. These are the same "conversion slugs" used in TV receivers, with turret (standard-coil) tuners. Very late model field-strength meters provide coverage on both u.h.f. and v.h.f. bands, just as the later TV sets do. A bit of practice will soon acquaint the technician with the readings needed for producing good clear pictures.

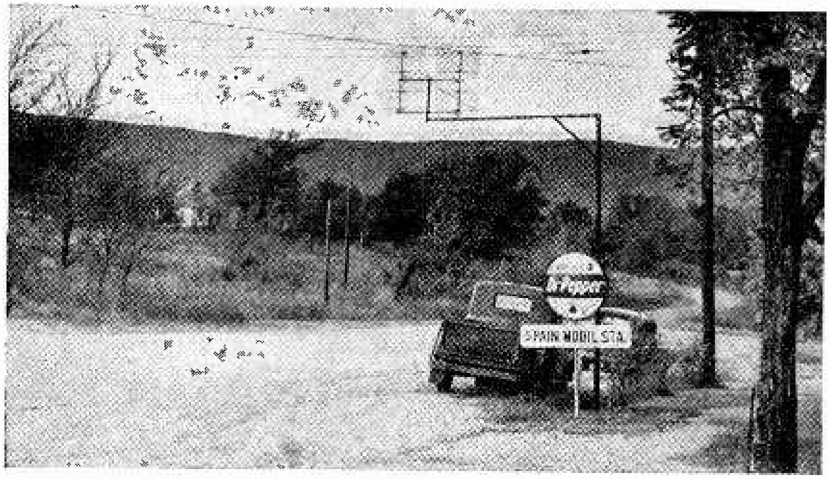
Positioning of the U.H.F. Aerial.—Because of the very high frequency, it is possible to move an antenna a full wavelength in any of the three directions, in a very small space, with a resultant change in signal quality! Therefore, when installing one of them, it behoves the technician to check for response in all directions. Not only this, but the angle of tilt, is critical! One installer found a good signal, fastened the antenna to the mast, and went below decks, leaving his helper to run the lead-in. To his dismay, he found only a very small signal at the set! After the inevitable wrong guess, that the brand-new lead-in was open, and some trouble, the awful truth was uncovered: when the helper attached the lead-in to the antenna, he had pulled it too tightly, causing the antenna to tilt upward in front a few degrees; this tilt resulted in a cancellation of the signal. Thus, when making u.h.f. installation, make sure that all mounting bolts, clamps, brackets, and the like are well snugged down!

Difficulties are often encountered in locating the signal, especially in obstructed areas, or in fringes. You may even find yourself in the position of one weary technician who had walked over the entire roof for an hour, only to hear shouts from below of, "Not yet! Not yet." Finally, in discouragement, he crawled down the ladder, leaned the probe antenna against the house, and lit a cigarette. He was startled to hear a happy roar from within, "Hey! There it is! Hoo, boy, looka what a picture! etc., etc." Rushing inside, he saw a perfect, snow-free picture. Needless to say, the antenna was installed at this point, on a very short bracket, just under the peak of the gable-end of the roof. This was the only spot in the entire area where enough signal was found to make a picture!

The technically trained traveller, motoring through a u.h.f. area, can brace himself for some weird sights. While a wee Yagi antenna perched atop the well-frame in the yard, or sitting quietly on a 3-foot mast in a ditch before the house, might not arouse much curiosity from the uninitiated, it will cause some raised eyebrows among the brethren!

Foliage attenuation, as mentioned earlier, can cause peculiar effects. If an antenna is installed behind a grove of trees or even a single deciduous tree, in winter, good pictures may be obtained. When summer rears her rosy head again, the pictures may become extremely fuzzy, causing quite a bit of head-scratching among the local technical gentry. This effect is due to multiple reflections from the leaves, especially if said tree is close to the antenna. These very closely spaced ghosts are indistinguishable, but they can give the picture a very badly out of focus look!

U.H.F. Converters and Tuners.—Many American TV receivers are being equipped with "all-channel" tuners, covering the v.h.f. and u.h.f. bands. Needless to say, these are actually dual tuners, in which the u.h.f. function is supplied by a separate valve, with associated circuitry; the output of this is generally on either an unused v.h.f. channel, or on the i.f. of the set. The u.h.f. channels, given numbers



"U.H.F. signals, like gold, are where you find them"—in this case over the middle of the road!

ranging from 13 to 83, may be dialled by rotating the "fine-tuning" knob, on some sets, or by a u.h.f. knob, behind the fine tuner, on others.

Sets equipped with a standard turret tuner may be easily converted for u.h.f. reception by removing an unused channel coil and installing a fixed-tuned u.h.f. converter "slug" as they are called for some reason. These generally use a converter crystal with the output on the i.f. of the set. With the incremental-inductance, or switch-tuners used by so many makers, because of their economy, an "outboard" converter is used. This little "black box" sits on top of the TV set, and contains the same type of circuitry; it converts the u.h.f. into an unused v.h.f. channel frequency. After some slight difficulties with converters in the early production, mostly due to unreliable u.h.f. tubes, these have proven very successful, and the majority of conversions use the outboard converter, with good success.

U.H.F. and the Technicians.—Although it was feared by many during the early days that u.h.f. would prove to be very unpopular with the technical gentlemen charged with repairing and maintaining these sets, these fears have proved groundless, fortunately. Although the expected amount of difficulty was encountered, it was not an insurmountable obstacle, and a large group of technicians interviewed in a recent survey said that they preferred u.h.f. to v.h.f., in many ways, and that they were having very few troubles with it, *per se*. One of the few complaints heard concerned the poor quality of tubes furnished in u.h.f. converters, and, as we just mentioned, this was some time ago: this trouble has apparently been permanently cleared up, for no complaints have been heard on this score for quite a while.

Noise Immunity.—U.H.F. enjoys one major advantage over v.h.f.: its comparative immunity from natural and man-made noise disturbance. Lightning and atmospherics bother these tiny signals very little, and the old bugbear of v.h.f. viewers, especially those unfortunate enough to reside on or near a trunk highway, automobile ignition noise, is so small as to be almost non-existent. The only troublesome effect found in u.h.f. is a peculiar interference found in sets installed on the side of a highway or street *away* from the station: these would jump and jitter every time a car passed. This was finally traced to reflections, signals bounced off the metal tops of the passing cars into the antenna! (Incidentally, since the American car of recent vintage seems to be getting lower and lower, at least to hear the makers tell it, perhaps we shall not be bothered with this much longer. If the present trend continues, the cars will be so low that they won't be able to reflect signals into the antenna!) Until this happy day arrives, the trouble may be obviated, if not eliminated, by moving the antenna either higher, or farther back on the building, or, if close to the transmitter, by tilting it upward. This phenomenon might be called sort of an "upside-down airplane effect"!

Let us conclude this discussion of u.h.f. with the tale of the Optimistic Soul. The O.S. was a technician; he lived in a small village about 35 miles away, airline, from a low-powered u.h.f. station. Between them were two ranges of hills, one of which was only two miles or so away. He was solemnly assured, with much tutting and head-wagging, that he'd "never git anything thar." But, armed with a field-strength meter on a long cord and a probe antenna, he set blithely about his task. His v.h.f. antenna was installed atop a 40-foot tower; reception from the v.h.f. station, in the same city, was only average. The laborious probing of the tower, top to bottom, produced only a good grade of snow; no pictures. Identical results were produced from a careful probing of the roof of his house. Anyhow, the O.S. was crossing the roadway, bearing the field-strength meter and probe antenna, accompanied by his small son, complete with the customary questions. "What's that thing on the stick, Daddy?" "Why were you climbing on the roof, Daddy?" *ad infinitum*. Halfway across the road, one question finally penetrated the O.S.'s weary ears. "Why is the little needle going all the way across, Daddy?" End of story, for all practical purposes: the signal was found, "loud and clear, for several blocks," directly in the middle of the road! After consultation with the village elders, who firmly declined to re-route the road, he set up the antenna shown in the photograph, as far out over the road as possible, and wound up with consistently snow-free pictures!

There could be two morals to this story; one, that u.h.f. signals, like gold, are where you find them, and the other that you should always be sure to include Child, Small, Curious, One, in your probing kit!

"Television Aerials for Bands IV and V": The standard dipole polar diagram in Fig. 3 on page 13 of the January issue was inadvertently drawn for a vertical dipole, whereas for a horizontal aerial it should have been shown as a "figure of eight" with maxima at 0° and 180° and minima at 90° and 270° respectively. The relative maxima values shown are correct.

Measuring TV Aerial Performance

I.—Conditions to Achieve Accurate Results

By F. R. W. STRAFFORD*, M.I.E.E.

THIS article has been written with particular reference to the measurement and expression of performance of television receiving aerials. It is not limited to these, however, but its scope extends to any aerials, transmitting or receiving, for use in the frequency range from, say, 40 to 1,000 Mc/s.

In the simplest sense the measurement of aerial gain and directivity may be made by erecting a suitable radiating aerial, for example, a half-wave dipole connected to the output of an oscillator, and, at some distance from it, the aerial under test. This aerial is connected to a sensitive receiver and the resultant output is compared with a reference aerial, usually a half-wave dipole.

Unfortunately, the transfer of the experiment to another site, a change in the height or separation of the radiating and receiving aerials, or a change in the weather, will invariably produce a new set of results so that one is left perplexed and disappointed. It is, of course, the old story of failure to appreciate the many hidden factors. Almost any electrical measurement has hidden problems but the author knows of none as difficult as those encountered in aerial work.

Here are some of the principal factors to be considered:—

1. The test radiations must present a uniform field at the receiving site together with the correct polarization.
2. The height and separation of the radiating and receiving aerials must be carefully chosen.
3. The site must be flat, have sufficient area, and be free from reflecting objects.
4. Suitable radiating and receiving apparatus must be chosen.
5. The aerial under test must have its feeder correctly terminated and steps should be taken to avoid the effects of the feeder on the measurements.
6. A monitoring aerial must be used.

Test Radiations.—These must possess a plane wave-front and must be uniform over the region in which the test aerial is erected. If the radiating and receiving aerials are too close, or if spurious reflections are present, either or both will affect, adversely, the results. The radiating aerial may most conveniently be a simple half-wave dipole the axis of which is orientated in the direction of the desired polarization. The use of a distant radiator, for example, a TV transmission, is not recommended on the following grounds: (a) there may not be a plane wave at the test site, due to absorption, reflection and diffraction effects during propagation; (b) the amplitude will vary in accordance with the average modulation depth and there may be fading and variations due to aircraft; (c) the frequency cannot be varied in order to study its effect on gain and directivity; (d) the working hours are restricted; (e) power variations are always liable to occur.

* Consulting radio and electronic engineer.

Choosing Height of Radiating and Test Aerials.—The intensity of the electro-magnetic field from the radiator falls off inversely as the distance. Associated with a dipole radiator there are also the magnetic field due to the current in the dipole and the electric field due to the charges at its extremities. The former falls off as the fourth power and the latter as the sixth power of the distance. This near field, as it is called, to distinguish it from the far field of true electro-magnetic radiation, has fallen to negligible proportions at a distance of five wavelengths from the radiator. It might appear to be reasonable to work with this separation but this is not so as will later be proved.

It is desirable that the height of both radiating and test aerials be at least one wavelength above the ground. This secures horizontal propagation, and prevents the radiation resistance of the test aerial falling badly and mismatching the feeder impedance for which it is designed. At 45 Mc/s a height of about 25 feet will suffice. This would fall to about 6 feet at 180Mc/s but the results are likely to be upset by the presence of personnel unless remote control is used. In the author's experience it is desirable to keep to about 25 feet for all work. If greater heights are employed greater separation between radiating and test aerials will be required. The reasons for this will now be explained.

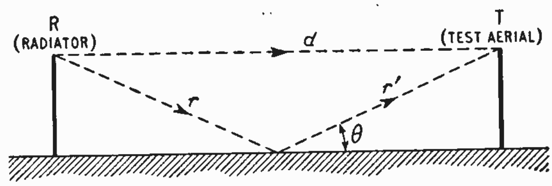


Fig. 1. Direct and reflected paths of test radiations sent from R and received at T.

Fig. 1 shows the radiating aerial, R, and the aerial under test, T, located at equal heights, h, over a flat ground at a distance, d, apart. The field at T is the vector sum of the direct field produced by the wave over the path d, and the reflected wave over the path r, r'. The resultant field, E_T, can be written as:—

$$E_T = E_D (1 - K\epsilon^{-jx}) \quad .. \quad .. \quad .. \quad (1)$$

In this expression K is the complex reflection coefficient of the ground and x, in radians, is the phase difference between the direct and reflected wave and is given by $x = 4\pi h^2/\lambda d$.

The magnitude of K varies with the conductivity and permittivity of the ground. It also varies with frequency and with the angle of incidence, θ, of the reflected wave. For v.h.f. and normal soils its value approaches minus 1, that is to say, the reflected wave is 180 degrees out of phase with the direct wave and almost cancels it. It is for this reason that the free-space field intensity, where there is no reflection, is very much greater generally than for propagation over the earth. This, however, is only true when the angle of reflection is very small. Over a range of angles from about 10 to 30 degrees according to the nature of the soil (wet, dry, sandy, chalky, and so on) there will exist a critical angle at which nearly all of the energy of the reflected wave will be absorbed so that the value of K will approach zero. In this case reference to equation (1) will show that the total field at the test aerial will be nearly equal to the free-space direct field E_D. So much

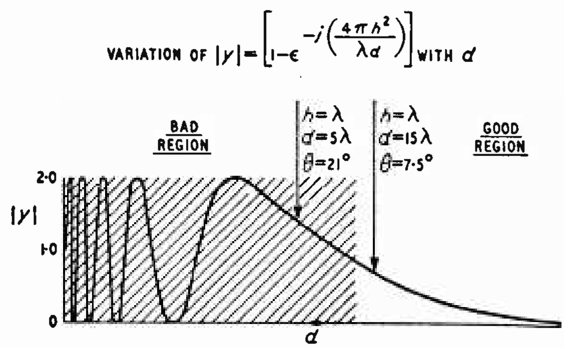


Fig. 2. With vertical polarization spacings d *within the shaded area for the test aerials should be avoided.*

for the reflection coefficient K. Putting $K = -1$ it is instructive to examine how the modulus $|y|$ of $(1-\epsilon^{-jx})$ varies with respect to d. For small values of d, $|y|$ oscillates between 0 and 2 and oscillates with infinite rapidity as d approaches zero. When d is large $|y|$ approaches the limiting value of $4\pi h^2/\lambda d$ which is non-oscillatory and is the good region for working. Unfortunately, when vertically polarized waves are considered K is not equal to -1 but tends to zero over the range of critical angles mentioned previously. Calculations show that all values of d within the shaded area of Fig. 2 are to be avoided. It all boils down to the fact that the angle of reflection θ sets the tune. If this is not greater than, say, 7.5 degrees the critical angle is avoided and so is the oscillating distribution, with distance, of the field at the test aerial. Hence, one is safe in working at a distance-height ratio of 15. For this reason it is undesirable to erect the aerials more than one wavelength high or the distances will become rather large, apart from the problem of obtaining an accurately variable source of power for the radiating aerial, as will be shown in a later section of this article.

Assuming that a height of 25 feet is chosen for Channel I (Band I) measurements the minimum spacing of the aerials will be of the order of 375 feet, but it is the writer's experience that this may be reduced to 300 feet without any observed inaccuracies. In this case the angle of reflection, θ, will be increased to 9.5 degrees but is still just clear of the critical angle range. Incidentally, this critical angle is known as the Brewster angle from that gentleman's work in optical theory. It does not exist for horizontally polarized radiation so that the spacing for tests on horizontal aerials can safely be halved. This is important for workers on horizontal aerials only, since the land may have to be purchased if a permanent test site is to be established. For the television aerial worker both polarizations are involved and it is a question of Hobson's choice!

The reader might be tempted to conclude that close spacing, say 5λ, could be used in spite of the large variations of total field at the test aerial with small changes of distance. He may argue that since both height and distance are fixed, the aerial under test, and the simple dipole with which it is to be compared are in the same field intensity, whatever value it may have. But the test aerial may be a six-element Yagi array. Its boom will be over one wavelength long. Over this distance the field intensity can vary by over 100 per cent so that each element of the array will experience a different field intensity. This has the effect of destroying its performance in terms of gain and directivity.

Choice of Site: For work down to 40Mc/s it has been shown that a separation between aerials of not less than 300 feet is essential if the aerials are mounted at a height of 25 feet. If the work is restricted to Band III the height could, theoretically, be reduced to about 6 feet and the separation to 75 feet. The low height causes problems due to the comparable height of personnel and unless remote control is used it is best avoided. Very considerable variation of both gain and directivity occur through quite small movements of personnel, but when the height is increased to 25 feet these vanish.

Provided that there are no reflecting objects the width of the site is unimportant. One could use a strip of land just wide enough to accommodate the paraphenalia. Thus, a strip of land 300 feet by, say, 15 feet would be satisfactory if it were located in the wide open spaces.

One must be practical and assume that some reflecting objects may exist and the question is, how far distant must they be before their effects impair the measurements?

The major effect of reflections is to upset the measurement of directivity. If the minimum distance of a good reflector can be deduced in terms of maintaining accurate directional response the gain will also be unaffected. In fact, a much greater amount of reflection can be introduced if gain measurements only are contemplated; but since it is most unlikely that this will occur in practice the worst condition must be avoided.

The cause of a false directional response due to reflections may be seen by reference to Fig. 3. The radiating aerial, R, and the test aerial, T, are 300 feet apart. A perfect reflector, such as will be closely approached by a large gas holder, is situated at a distance x behind the test aerial. In the first place assume that the test aerial has excellent directivity, that is, a narrow beam in one direction and zero response in all other directions. This narrow beam is shown in Fig. 3(a). In the absence of any reflection the test aerial will pick up a rapidly diminishing signal as it is turned off-line from the radiator R. Reception will, of course, be zero when it is turned in the opposite direction. If the reflector is present the reflected signal coming back to the test aerial will also be received so that the beam will now appear to possess a back-lobe whose amplitude, in relation, to its forward lobe, will depend on the distance and the efficiency of the reflector (Fig. 3(b)). By the same process a number of reflectors located around the test aerial will produce an equal number of false lobes the individual amplitudes of which will be dependent upon the size and distance of the reflecting object (Fig. 3(c)). It has been shown[1] that the strongest reflections are those from objects behind the test aerial as shown in Fig. 3.

The calculation of the minimum distance of the worst type of reflection is not a simple matter. This distance is determined by the maximum front-to-back ratio likely to be given by the aerial under test. Experience indicates that this is not likely to exceed 30dB so that the reflected signal must be at least 40dB below the incident signal.

Since it is impossible to calculate, with any accuracy, the magnitude of the reflection from buildings and other structures the practical assessment of the degree of reflection may be made by measuring the standing-wave ratio of the combined direct and reflected field over the region in which the test aerial is to be sited. If two waves of equal frequency arrive at a point from opposite directions a standing-wave pattern will be set up and the ratio of the maximum to minimum amplitude will depend upon the ratio of the amplitude of the respective waves.

Let E_1 be the amplitude of the direct wave and E_2 the reflected wave, and let their ratio be n. The standing-wave ratio is given by the expression:

$$r = \frac{E_1+E_2}{E_1-E_2} \text{ or, } r = \frac{1+\frac{1}{n}}{1-\frac{1}{n}} \quad \ldots \quad \ldots \quad (2)$$

The magnitude of the reflected field in dB below the direct field will be:

$$z(\text{dB}) = 20 \log_{10} \frac{r+1}{r-1} = 20 \log_{10} n \quad \ldots \quad (3)$$

so that if z is to be reduced 100 times (40dB) the standing-wave ratio works out to 1.02.

To measure such a ratio, which is very nearly unity, requires great care. A test dipole, fed by a feeder located along its axis, is arranged so that it can be moved radially about its position. The object of running the feeder in the direction of the axis of the dipole is to prevent reflections from the feeder masking the result. The height of the dipole must be accurately maintained since the field intensity is also proportional to this. Fig. 4 is a sketch of a suitable arrangement, and it must be erected over very flat ground. The boom must be at least half-wave in length and the probe can be arranged to slide along it by a rope and pulley arrangement.

[1] Lawson, D. I. "Multipath Interference in Television Transmission," *Journ. I.E.E.* 1945, Vol. 92, Part III, page 125.

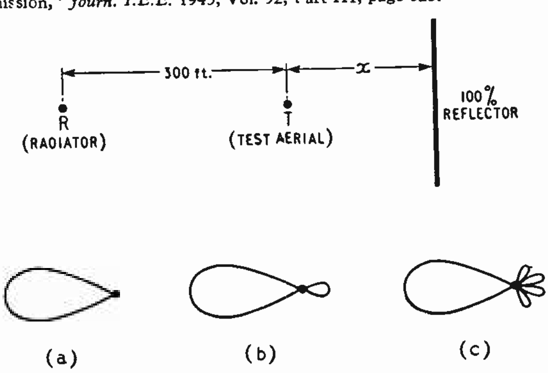


Fig. 3. Affect on the polar diagram of a reflecting object behind the receiving aerial, T.

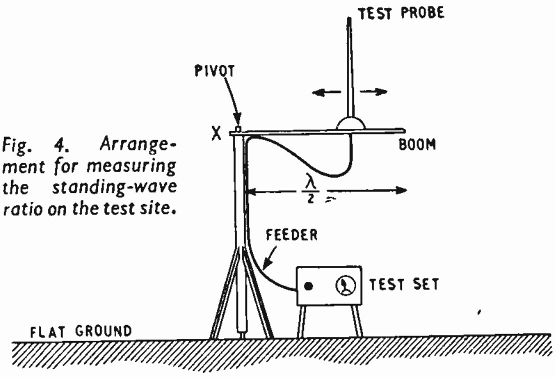


Fig. 4. Arrangement for measuring the standing-wave ratio on the test site.

The procedure is to explore the standing-wave ratio by setting the boom at various angles and sliding the probe from one end of the boom to the other. If the resultant does not exceed 1.02 consideration can be given to the selection of the measuring apparatus, the actual tests, and the expression of the results. These will be dealt with in part 2 of this article.

(*To be continued*)

CLUB NEWS

Birmingham.—"The development of magnetic recording tapes" is the title of a talk to be given by a representative of the Minnesota Mining and Manufacturing Co. to members of the Slade Radio Society on February 14th. A fortnight later J. E. Smith (G3JZF) will deal with the design and construction of a.f. amplifier stages. Meetings are held on alternate Fridays at 7.45 at the Church House, High Street, Erdington. Instructional morse classes are held on Tuesday and Thursday evenings, and slow morse transmissions are radiated by G3AYJ on 1.9 Mc/s at 8.0 p.m. on Mondays. Sec.: C. N. Smart, 110, Woolmore Road, Erdington, Birmingham, 23.

Birmingham.—The Midland Amateur Radio Society meets the third Tuesday of each month at 7.30 at the Midland Institute, Paradise Street. Morse classes are held every Thursday at 7.30 at the British Red Cross Society, 16 Highfield Road, Edgbaston. Sec.: C. J. Haycock, G3JDJ, 360, Portland Road Edgbaston, Birmingham, 15.

Bradford.—Dr. G. N. Patchett will speak on transistors and their application to radio at the meeting of the Bradford Amateur Radio Society at 7.30 on February 4th at the Bradford College of Technology. Sec.: D. M. Pratt, G3KEP, 27 Woodlands Grove Cottingley, Bingley.

Bury.—At the February 11th meeting of the Bury Radio Society J. E. Hodgkins (G3EJF) will talk about radio astronomy. Meetings are held on the second Tuesday of each month at 8.0 at the George Hotel, Kay Gardens. Sec.: L. Robinson, 56 Avondale Avenue, Bury.

Reading.—Selsyns and desyns will be discussed by S. Woodward at the meeting of the Reading Amateur Radio Group at 7.30 on February 22nd at the club's headquarters in Broad Street. Sec.: A. B. Hutchence (G3IKA), 12 Chiltern Bank, Peppard, Nr. Henley, Oxon.

Wellingborough.—At the meeting of the Wellingborough and District Radio and Television Society on February 13th G. Abrams will speak on basic f.m. detectors and at the February 27th meeting J. Wagstaff will describe a home-constructed 6-inch television receiver. Meetings are held at 7.30 every Thursday at the Silver Street Club Room. Sec.: P. E. B. Butler, 84 Wellingborough Road, Rushden.

Magnetism in Materials

(Continued from p. 30 of previous issue)

2. Ferromagnetic Domains and Their Influence on Magnetic Properties

By D. H. MARTIN, Ph.D.

THE concept of the magnetic domain was first put forward by Weiss in 1908 in order to explain how a spontaneously magnetized material could exhibit zero overall magnetization. The existence of domains was not fully confirmed experimentally until the last ten years or so, although a great deal of indirect evidence had already accumulated.

The idea is illustrated in Fig. 3. Each domain is spontaneously magnetized, to a degree determined by the chemical composition of the material and by the temperature, and in a direction different from its neighbours. The overall magnetization of a specimen is the vector sum of the magnetizations of its domains, with appropriate weighting for their volumes. The structure of Fig. 3 for example would leave a specimen with zero overall magnetization; it would be "unmagnetized" in spite of the intense magnetization in each domain. When a sample is subjected to an external field it becomes magnetized because there is a change in the sizes and directions of the domains; there is *no change* in the magnitude of the spontaneous magnetization, I_s.

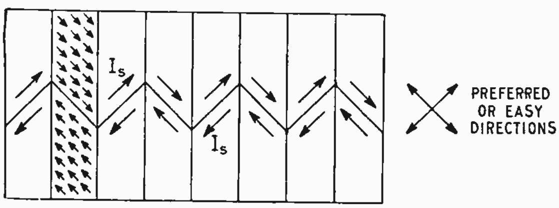


Fig. 3. Example of the arrangement of spontaneous magnetization in a domain structure. The alignment of atomic dipoles is illustrated in two of the domains.

These processes will be discussed more fully later, but first let me describe the experiments which have shown that domains really do exist. If a crystal of a ferromagnetic metal is carefully polished mechanically and electrolytically to remove the strained layers in its surfaces, and then a drop of a colloidal suspension of magnetic particles is applied to one of its faces, examination under a microscope reveals patterns formed on the surface by the particles. Magnetite is ferrimagnetic and the particles, which are about 10^{-6} cm in diameter, therefore move to where the stray fields close to the surface are most intense, just as iron filings cluster at the poles of a magnet. The surface fields arise, of course, from the domain structure in the surface layer of the crystal and, if the crystal face has a suitable crystallographic orientation, the patterns directly reveal the underlying domains. The photograph in Fig. 4 (a) was taken through a microscope and shows the domains in a crystal of cobalt. The parallel lines of dark magnetite particles mark the boundaries between domains which are spontaneously magnetized as shown in Fig. 4 (b). There are normally several domains in each crystallite of a metal, but even so each domain contains at least 10^{16} atoms. In the large crystals which have been grown especially for studies of domain processes the domains are sometimes as large as a few millimetres in each dimension.

The boundaries between domains are narrow regions in which the spontaneous magnetization changes direction progressively from one domain to its neighbour. In iron the domains walls are about 10^{-5} cm wide, that is about 300 atoms wide. In certain very soft materials, such as "Supermalloy", the walls are perhaps as wide as 10^{-3} cm.

Magnetic Anisotrophy

It is found that in the absence of an applied field each domain in a crystal is magnetized in one of a small number of *preferred*, or *easy* directions, an effect known as *magnetocrystalline anisotrophy*. In

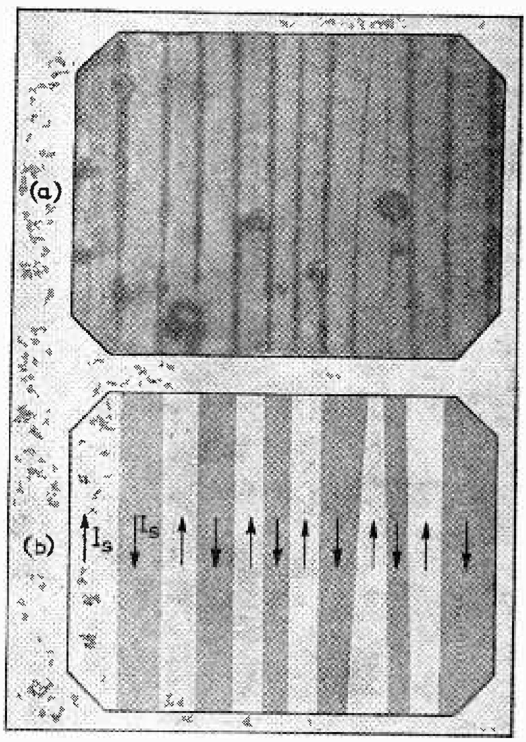


Fig. 4. (a) Photograph taken through a microscope of a powder pattern on a crystal of cobalt. The portion of the crystal recorded is about 0.025 inch across. (b) Sketch illustrating the domain structure revealed by the pattern.

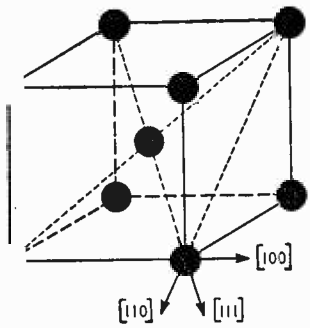


Fig. 5. Arrangement of iron atoms on a "body-centred cubic lattice." The "Miller indices" of the directions of highest symmetry are indicated.

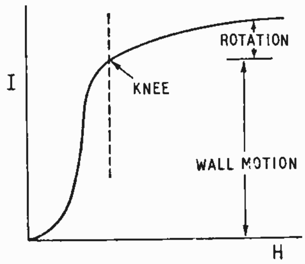


Fig. 6. A magnetization curve. The increa·e in I, as far as the "knee" of the curve, is mainly due to domain wall mevement. The less steep rise in I, beyond the knee, is mainly due to domain rotation.

most ferromagnetic materials the atoms in each crystal are arranged on a cubic lattice; iron atoms, for example, being arranged as illustrated in Fig. 5, in a fashion known as body-centred cubic. Those directions parallel to the cube edges are denoted by the Miller indices [100] and in iron it is these directions which are preferred. Counting both senses for each edge they are six in number. In nickel the eight cube diagonals, that is the [111] directions, are preferred. Cobalt on the other hand is magnetically uni-axial and domains are magnetized parallel or anti-parallel to the hexagonal axis in each crystal. Only in the presence of a comparatively strong applied field can the spontaneous magnetization rotate away from the preferred directions.

Wall Movement. As the field applied to a sample is steadily increased its overall intensity of magnetization increases, generally as illustrated in Fig. 6. The dominant domain process occurring in the specimen in the early portion of the curve is different from that in the later stages. In the first part, the magnetization rises steeply to more than half its final saturation value. Thereafter the rate of increase of magnetization with field is reduced. The steep rise is due mainly to *domain wall movement*. For example, consider the domain structure illustrated in Fig. 3. If a field were applied to a specimen containing this structure in the direction left to right, those domains in the upper half would be favourably directed with respect to the field, compared with the lower domains. They would therefore grow at the expense of the others as a result of a downward displacement of the saw-tooth wall running across the structure. Microscopically, the displacement of a domain wall is the progressive rotation of those atomic dipoles in the vicinity of the wall out of the direction of magnetization of the shrinking domain into that of the expanding one. This is a process which takes place comparatively readily under the action of an applied field since all the domains remain magnetized in one or other of the preferred crystal directions. The colloidal magnetite technique can be used to study wall movements. The photographs in Fig. 7 show successive wall positions in a cobalt crystal which was subjected to a steadily increasing magnetic field.

Wall movement will proceed until a stage is reached when no further increase in magnetization can result from wall movement alone. For example, take the structure of Fig. 3. When the saw-tooth wall has moved to the bottom of the structure the remaining domains are equally inclined to the field, and displacement of the walls separating them would achieve nothing. The specimen is then at the "knee" of its magnetization curve. The specimen's overall magnetization can now increase only as a result of rotation of the spontaneous magnetization within each domain as a whole. As the applied field increases further, therefore, the directions of magnetization

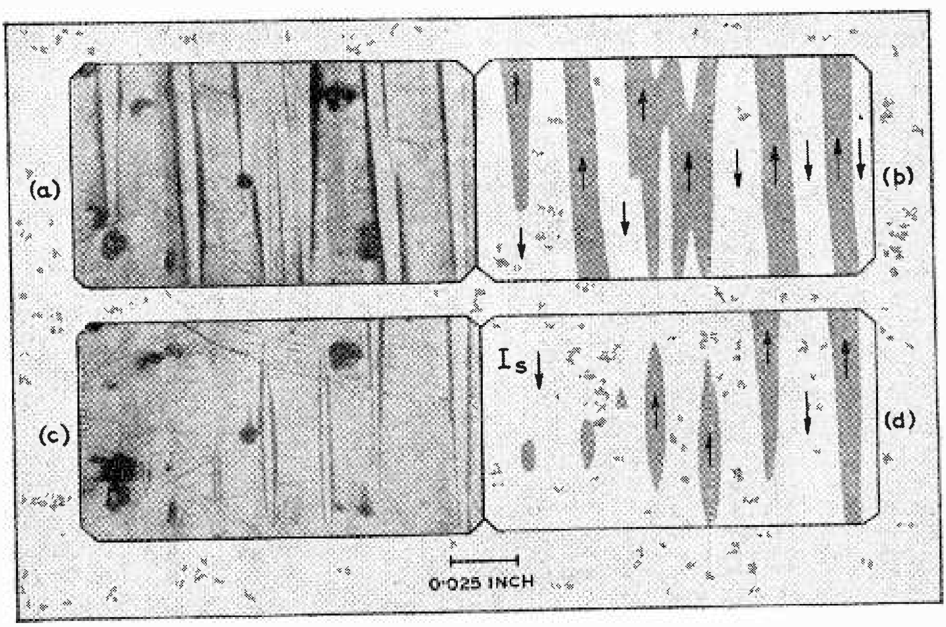


Fig. 7. Domains in a cobalt crystal. (a) and (c) cover the same portion of the crystal's surface but a field has been applied in the downward direction in the case of (c). The domain walls have moved in such a direction that the unfavourably magnetized domains have shrunk, as illustrated in the sketches.

in the domains progressively rotate towards the field. Relatively large fields are required in most materials, however, to produce large rotations against the anisotropy forces, and the magnetization curve rises progressively less steeply. Saturation is achieved when all the domains are aligned with the applied field, and the overall magnetization is then equal to the spontaneous magnetization.

The dual process of magnetization is most clearly revealed in the magnetization curves of single crystals, such as those shown in Fig. 8. Using special heat treatments it is possible to grow very large crystals in metal ingots, and the growth in our understanding of magnetic materials in the last ten years has largely been the result of experiments on such crystals. The magnetization curves in Fig. 8 are for crystals of iron to which is applied a magnetic field respectively in a [100], a [110] and a [111] direction (see Fig. 5). For the [100] case, saturation is attained in a

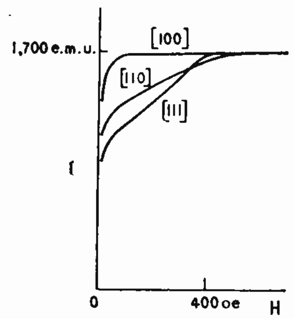


Fig. 8 Magnetization curves for the [100], [110] and [111] directions of a crystal of iron.

small field because [100] is a preferred direction and saturation can be achieved by domain wall movement alone. For the [110] and [111] cases wall movement alone can produce a magnetization equal to $1/\sqrt{2}$ and $1/\sqrt{3}$ of the saturation magnetization respectively; subsequent increases in magnetization are due to rotation. The scale of Fig. 8 is too small to record the rise to the knees of the curves which takes place, by wall movement, in small fields.

Anisotropy Constants. Rotation takes place more readily in some magnetic materials than in others and the effect is measured in terms of the "anisotropy constants" of the materials. It is found that to rotate a domain's magnetization from a [100] direction into a direction having direction cosines* (α_1, α_2, α_3) the applied field must do work equal per c.c. to:

$$E_K = K_1(\alpha_1^2\alpha_2^2 + \alpha_2^2\alpha_3^2 + \alpha_3^2\alpha_1^2) + K_2\alpha_1^2\alpha_2^2\alpha_3^2$$

where K_1 and K_2 are the anisotropy constants of the material. For the [111] direction for example, $\alpha_1 = \alpha_2 = \alpha_3 = 1/\sqrt{3}$ and E_K is thus $\frac{K_1}{3} + \frac{K_2}{27}$ while for the [110] direction $\alpha_1 = \alpha_2 = 1/\sqrt{2}$ and $\alpha_3 = 0$; E_K is then $\frac{K_1}{4}$. Measurements of the magnetization curves in these two directions therefore serve to determine K_1 and K_2, and knowing these the energy associated with magnetization in any other direction can be calculated using the equation above. It is then possible to calculate the shape of the magnetization curves of single crystals in the rotation region whatever the direction of the applied field with respect to the crystal axes. It is more difficult to calculate the magnetization curves of polycrystalline samples because the field *inside* the specimen will vary somewhat from crystal to crystal, but for appropriate cases calculations have been made and agree satisfactorily with measured curves. Clearly, the larger the anisotropy constants, K, for the material, the less steeply will its magnetization curve rise above "the knee." For materials whose easy axes are [100] directions K_1 is positive, and for those with [111] easy axes K_1 is negative.

*The cosines of the angles between the direction concerned and the three cube axes, i.e. the three [100] directions.

Magnetostriction

Before going on to consider the magnetization curve below the knee, where wall movement, and not rotation, is the dominant mechanism (but where, nevertheless, the magnitude of K proves to be a most important consideration) I must deal briefly with the influence of mechanical stresses in magnetic materials. It is well known that specimens of some materials expand in length a minute amount when subjected to a magnetic field, while other materials contract. This is "magnetostriction" and is the basis of magnetostriction oscillators. Fundamentally it is due to the fact that tension in a crystal very slightly distorts the lattice and the preferred direction is then determined not only by the lattice directions but also by the magnitude and direction of the tension. The effect is measured in terms of the "magnetostriction constants" of the material, which may be determined by observing the changes in dimensions of a test single crystal when it is saturated in different crystal directions. The magnetostriction constants, which I denote by λ, may be positive or negative (expansion or contraction), and three are needed in the case of a cubic crystal. The larger λ the greater the effect of mechanical strain in determining the favoured direction of magnetization. Magnetic materials are not often used in uniformly stressed conditions, but it is not possible to produce a material which is entirely free from random small-scale strains, and in the presence of these it will be seen that the magnitude of λ is of importance in connection with wall movement.

Hysteresis

In a perfect crystal a domain wall would move under the influence of an infinitesimally small applied field. Real materials, however, require the application of definite fields to reach the knee of the magnetization curve. Highly refined 78% nickel-iron alloys require only about 0.002 oersteds whilst special permanent magnet alloys of the Alnico type may require several hundred oersteds and between these extremes fall all the useful magnetic alloys. The impedance to wall movement arises from the impurities and random stresses which are always present to some degree even in the most carefully prepared materials. The impedance, moreover, is *irreversible*, or "frictional" in the sense that switching off a field which has been applied to move a wall forward does not result in the wall's returning to its initial position. In fact the application of a reverse field would be required to do this. This, of course, leads to the important

(*Continued on page 73*)

"BELLING LEE" NOTES

PRINTED CIRCUITS

A few months ago, we were called to task because one of our distribution amplifiers was not performing as well as was expected. The matter was investigated; the amplifier was tested, on its own and appeared to be up to specification. When the installation was examined it was found that a diplexer not of our design was in the circuit. When this was replaced by one of ours, the efficiency of the installation was normal.

The point of this factual story is that the dealer blamed the printed circuit diplexer and implied that all printed circuit "jobs" were alike. Now that was most unfair; printed circuit techniques are here to stay, and if properly handled, the diplexer equipment or what-have-you is just as good as the circuit designer has made it.

KEEP ON PROBING

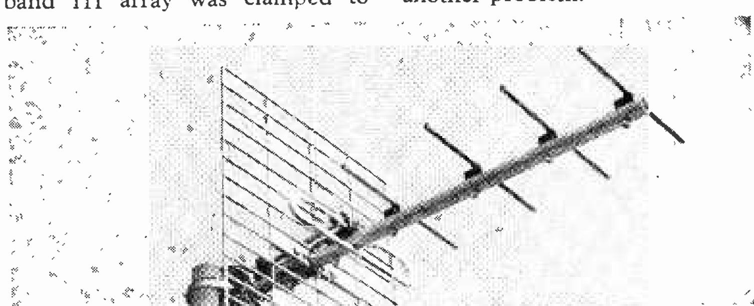
Recently we had some interesting work to do on a television installation in a particularly tricky area about twenty-four miles from the transmitter, but low lying in relation to the surrounding country. The mast was a remarkably useful "home-made" one capable of being raised or lowered vertically, and of being rotated. At the top was a band I and a double 6 band III. The band III picture was not as good as it should have been, and we decided to carry out an investigation which, incidentally, was carefully followed by a prominent senior engineer specialising in electronics.

As a first test, a six element band III array was clamped to the mast about six feet above the roof, as a reference. The resulting signal was better than that from the double six at the mast head. Then, as a matter of interest, the lower six was raised while we were able to look at the picture. As the distance from the roof increased, the picture changed from good to bad. Going through various stages, the picture would tear, then it would get better, further up two or three ghosts would appear, then it would tear again and so on.

The double six was rotated through 360° without much effect, as reflections came in from all around. The single six was directional. There was more than enough signal, but there were still ghosts. We then tried a double three about 20 feet above the roof, this got rid of the ghosts and left us with ample signal.

We would like to have tried further positions, but the light was failing, we were far from home and everybody was satisfied.

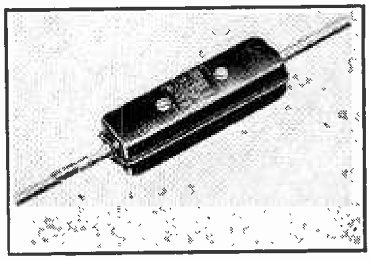
The lesson to be learnt from all this is that in a difficult location, best results cannot be expected just by putting up the biggest aerial as high as possible. The biggest aerial may not be the best to use, and the site must be probed for the best signal, and probed at various heights. Generally we say go as high as you can, but this is not an invariable rule. There is the site at Hebden Bridge, 12 miles from Holme Moss, where the only signal was from a "Doorod" in the cellar, but that was another problem.



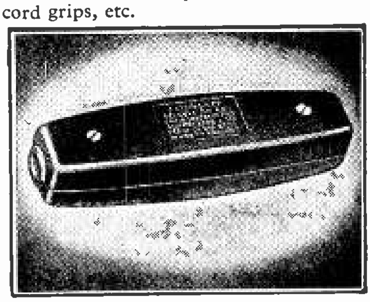
Band V Arrays. We are in production with these aerials and have supplied them to the B.B.C. and other authorities. Write to us if you are interested.

Advertisement of
BELLING & LEE LTD.
Gt. Cambridge Rd Enfield, Middx,
Written 9th December, 1957

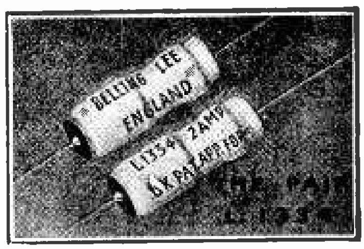
"BELLING-LEE" INTERFERENCE FILTERS



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



L.797. (2- or 3-core) 2 amp. 250 v. A.C./D.C. Inductor and capacitor filter effective at band I television frequencies and short and medium wavebands. This is a filter designed for connection in the lead of domestic electrical equipment such as hair dryers, vacuum cleaners, sewing machine motors, electric fans, etc., and to be truly effective must be fitted *within* 6in. of the connections of the motor in the appliance.



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

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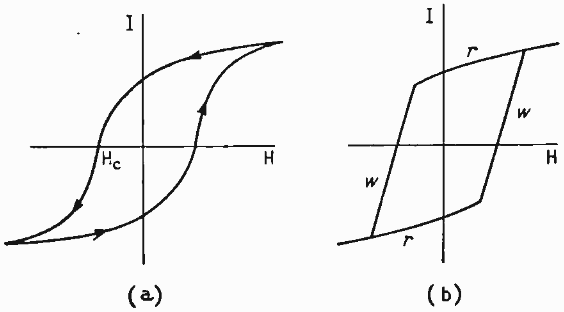


Fig. 9 (a) Typical hysteresis loop. As the applied field alternates the magnetization I follows the loop in the direction indicated. (b) Explanation of hysteresis in terms of rotation (r) and impeded wall motion (w).

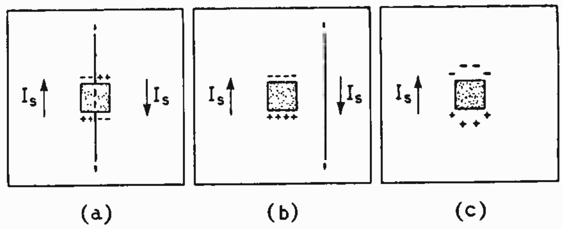


Fig. 10. Effect of a non-magnetic inclusion (shaded).

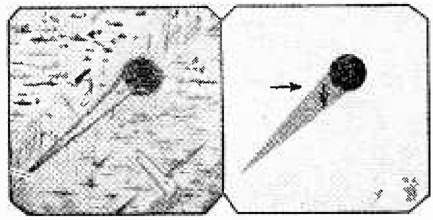


Fig. 11. The rotation of I_s close to a pit in the surface of a silicon-iron crystal has resulted in the formation of a spike domain.

phenomenon of *hysteresis*. When a specimen is subjected to an alternating field its intensity of magnetization varies cyclically as illustrated by the hysteresis loop of Fig. 9(a). The general form of the curve is explained in terms of simple domain theory in Fig. 9(b). Domain rotation is normally reversible and thus gives rise to no hysteresis. In the wall movement region of a magnetization curve, however, the " frictional " resistant to wall motion causes the curve to open up into a hysteresis loop.

The way in which impurities impede the movement of a domain wall can be seen by reference to Fig. 10 which illustrates a cubical non-magnetic void or inclusion in a ferromagnetic material. In Fig. 10(a) a domain wall bisects the inclusion. The magnetization diverges at the edges of the hole, that is, forms "free poles" there, and, since the spontaneous magnetization to the left of the domain wall is opposite to that in the right, the pole distribution is rather like that associated with two short bar magnets lying side by side with north pole next to south. Suppose now that the wall moves beyond the inclusion as in Fig. 10(b). The pole distribution round the inclusion is now like that associated with two magnets with their north poles together. It is well known that in order to twist two bar magnets from the stable anti-parallel arrangement into the parallel situation work must be done; or putting this another way the magnetostatic energy of the first arrangement is much less than that of the second. This also applies to the pole distributions round the inclusion and in order to move the domain wall from the position in Fig. 10(a) to that in Fig. 10(b) the field must do work. This is the origin of the impedance to wall motion. In a real material the impurities form many non-magnetic inclusions randomly arranged, and the energy associated with a moving domain wall fluctuates, being low in those positions of the wall where it happens to bisect a large number of inclusions, and being relatively large when it bisects few. A wall will stay in a position where the associated energy is low until moved by an applied field. If the field is then switched off the wall will slip into the nearest energy minimum and stay there until a field is applied again.

The effect of an inclusion is a little less simple than is illustrated in Figs. 10(a),(b), because the stray fields due to the free poles at the inclusion tend to rotate the spontaneous magnetization out of the preferred direction in the region close to the inclusion. The result is that the free poles, instead of appearing at the edges of the inclusion, are spread through a volume somewhat larger than the inclusion, as is illustrated in Fig. 10(c); and the impedance to the wall motion is consequently less than for the simple case. Now the rotation effect will be the more marked the smaller the anisotropy constant K. The conclusion therefore, is that for a given impurity distribution, the larger K the greater will the hysteresis be and the smaller the initial and maximum permeabilities. This conclusion has been amply demonstrated especially with certain silicon-iron and nickel-iron alloys discussed in detail in a later section.

A given amount of impurity causes the greatest impedance when it is dispersed through the material in the form of particles having a diameter about equal to the width of a domain wall, which in iron means about 10^{-5} cm, but in Mumetal considerably larger than 10^{-5} cm. Carbon, sulphur, oxygen and nitrogen are probably the most troublesome impurities in practice and much attention is paid to eliminating them. The influence of non-magnetic inclusions can be observed directly, in the case of large pits in the surface of a crystal of iron, using the powder pattern techniques described earlier. At a large inclusion the rotation mentioned above takes place to such an extent that small spike-like domains are formed like that illustrated in the photograph of Fig. 11.

Wall motion is also impeded by residual mechanical strains which exist in any real material however carefully prepared. In a region of stress the preferred direction of spontaneous magnetization is determined not solely by the crystal lattice but also by the direction of tension. The spontaneous magnetization is therefore very slightly rotated by the random tensions with the consequent formation of islands of " free poles " similar to those due to non-magnetic inclusions. These give rise to wall impedance. The greater the magnetostriction constant of the material the greater is the influence of tension and therefore the greater the hysteresis and the smaller the permeability. This fact will be illustrated later when describing the remarkable Permalloy and Mumetal alloys.

Powder Magnets

I have stressed that large increases in magnetization which occur in small applied fields are due to domain wall movement. It has recently been found possible to make materials which contain no domain walls. Specimens of these materials are made up of minute powder particles and have become important because of their use in recording tapes and permanent magnets.†

In these materials the process of magnetization takes place only by domain rotation. In order to discuss them it is necessary to ask why domain

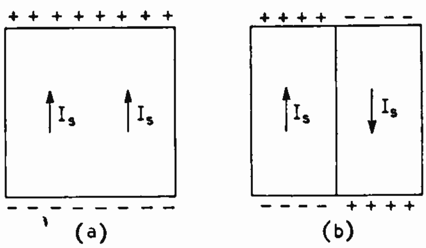


Fig. 12. Magnetostatic energies for single- and multi-domain specimens.

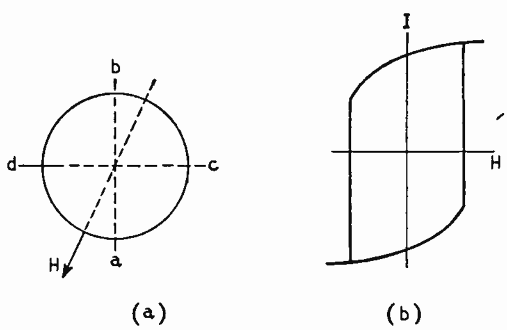


Fig. 13. Illustrating irreversible rotation in single-domain particles.

walls should ever appear in a material. Energy must be provided if the area of wall is to be increased. This is because the electron spins within a wall are not perfectly aligned as the exchange forces would have them; their direction changes through the wall from one domain to the other and they therefore possess exchange potential energy. A domain wall can therefore form in a specimen only if its presence leads to a reduction of some other energy. Fig. 12 illustrates the alternatives. In the absence of domain walls a specimen will be a single domain as in Fig. 12(a). In Fig. 12(b) a wall divides the specimen into two domains. Now the magnetostatic energy associated with the two domains of Fig. 13(b) is equal to that of two bar magnets lying together with the north pole of one next to the south pole of the other. The magnetostatic energy of the single domain in Fig. 12(a) on the other hand is like that associated with two bar magnets whose north poles are together, and is therefore quite clearly larger than that of the two domains. The introduction of a domain wall thus reduces the overall magnetostatic energy and this is the basic reason why domains form.

The magnetostatic energy of a single domain is roughly proportional to its volume while the energy of a wall would be proportional to the area of cross-section. The smaller the specimen therefore the smaller the ratio between the magnetostatic energy and the domain wall energy, and for particles smaller than a certain size the introduction of a domain wall would in fact increase, not decrease, the total energy. Such particles will remain in a single domain state, containing no domain walls. The domain wall energy in iron is approximately 1 erg/cm^2 while the magnetostatic energy of a spherical single domain of radius R is $\frac{8}{9}\pi^2 R^3 I_s^2$ where I_s is the spontaneous magnetization, which is for iron about 2×10^3 e.m.u. The critical size for a single domain particle of iron is therefore of the order of 10^{-6} cm diameter. Powders of iron showing properties approaching those of single domains have in fact been produced. For some materials the wall energy is larger than for iron whilst I_s is smaller; this is especially so for certain ferrites. These materials consequently have a much greater critical size of a micron or so, and single domain powders are fairly easily produced. Since there are no walls in single domain particles magnetization can proceed in the presence of an applied field only by *rotation* of the spontaneous magnetization. Although rotation in normal materials is mainly reversible, in the absence of domain walls irreversible rotation processes giving rise to hysteresis occur. As an illustration of this consider Fig. 13(a). In the absence of an applied field the spherical single-domain particle is spontaneously magnetized in a preferred direction, say a-b. The least preferred direction, that is to say the direction in which the spontaneous magnetization would have its largest energy, is say c-d. If a steadily increasing field is applied as shown the magnetization will rotate towards c-d, the field providing the necessary energy. When it reaches a certain direction lying between a-b and c-d, however, instability occurs because further rotation results in a decrease in the magnetic energy which is larger than the accompanying increase in anisotropy energy. The spontaneous magnetization therefore rotates intantaneously into a direction close to the magnetic field. If the applied field is now reversed so also is the rotation process. The hysteresis loop for the particle therefore resembles the illustration in Fig. 13(b). If K is the anisotropy constant, it is not difficult to show that coercivities of the order K/I_s should result, and the permanent magnet powders discussed later do exhibit coercivities approaching this ideal. The anisotropy considered above is magnetocrystalline; it is possible to produce needle-shaped particles which are magnetically anisotropic because of their shape, since the magnetostatic energy in such a particle is least when the magnetization is in the direction of the longest axis. Ideal coercivities for this case are of the order $2\pi I_s$, that is greater than 9,000 oersteds for iron.

(To be continued)

†The application of powder specimens in high-frequency inductors and transformers is based on a different principle.

Combined Test Prod and Clip

By C. BAYLEY

Simple Design Allowing the Addition of Screening and an Isolating Capacitor

IN the electronics industry the time lag between the development of new components and of the tools for servicing them is (with the possible exception of the soldering iron) much longer than might be expected. For example, the crocodile clip remains much the same as it was, say, 20 years ago; but during this same period the size of components has been halved at least. Consequently the usual crocodile clip becomes almost useless for anchoring to an ordinary B7G valve base pin for instance, and much time and effort is wasted. Another inconvenience becomes obvious when changing from a prod to a clip. Not only must the tool be changed over, but re-connection of the test lead to the other end is also necessary. Now, when on top of all this we remember that, in general, electronic equipment is far more complex nowadays, we can see that the development of a modern combined test prod and clip seems necessary to help reduce the time required for testing.

This article gives a detailed description of two versions of such a tool. The first consists of a long insulating shaft with a handle at one end from which jaws at the other can be opened by an internal wire. The second version is similar, but with the addition of screening and an isolating capacitor with shorting switch.

General Features Required.—Before we come to the detailed description of the construction let us see what conditions must be fulfilled by a satisfactory design for such a tool. These are as follows:—

1. The jaws of the clip and the whole front part of the tool must be narrow, but yet give a sufficiently strong grip.

2. Changing from clip to prod and vice versa, and also anchoring and disconnecting the jaws from the tested part must be easily carried out with one hand at a distance from the jaws.

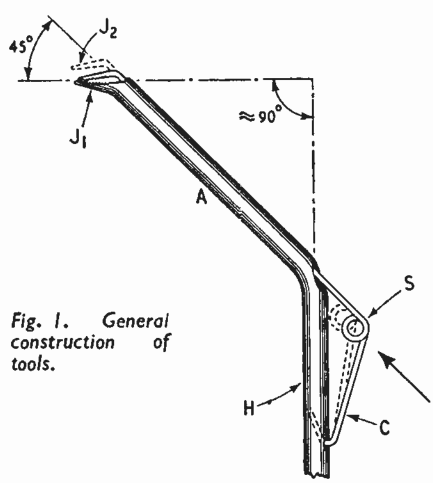


Fig. 1. General construction of tools.

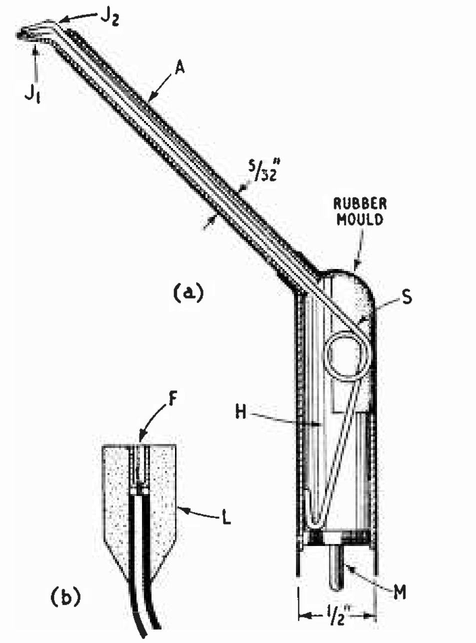


Fig. 2. (a) Construction of simple model. (b) Lead-in to simple model.

3. Convenient application of the tool to the apparatus to be tested must be possible. For example, the tool must not obscure the area under test.

4. The tool must be entirely insulated, with the exception of the small exposed part of the jaws (say ¼in long).

5. In the case of the version with an isolating capacitor, short circuiting this capacity must be readily possible.

6. The tool must be light and dependable.

Principle of Operation.—Fig. 1 shows the basic construction of both models. The top end of the tubular metal arm A is bent through about 45° to form the lower jaw J_1. Steel piano wire is threaded through the arm A to form the movable part of the clip. At the top end this wire is similarly bent through a little more than 45° to form the upper jaw J_2. The jaws J_1, J_2 are normally held firmly together in the prod position by the action of the coil spring S and the portion of the wire C in the handle H. When the coil spring S is depressed in the direction of the arrow the jaws J_1 and J_2 are opened. (The new positions of J_2 and the wire S and C are shown dotted.)

From a consideration of the geometrical shape of such a structure two important points emerge. In

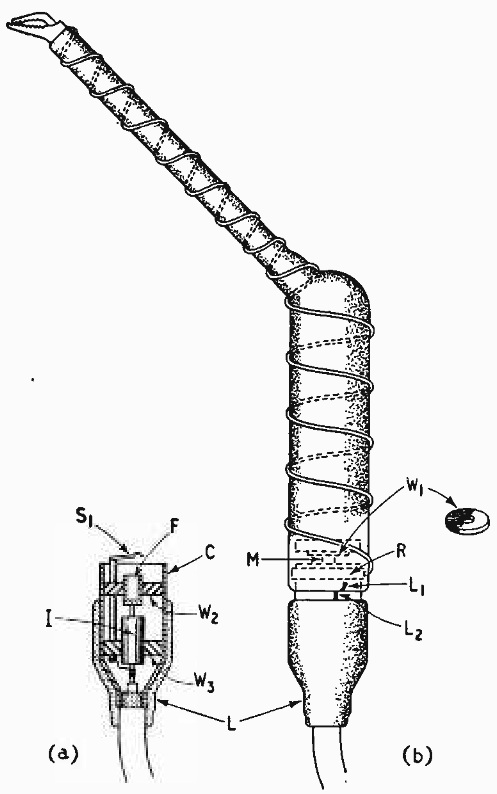


Fig. 3. (a) Construction of screened model. (b) Lead with isolating capacitor.

the first place, the arm A can have any required length: up to, say, 4 inches was found to be convenient. Secondly, taking into account the third design condition, the angle between the axis of the jaws and that of the handle H should be about 90°.

Simple Model.—Fig. 2(a) shows the full construction. The handle H becomes rather complex in view of the requirements of rigidity and overall insulation and yet also for ready manipulation of the spring S. The handle H is made of a metal tube with a single split along its length and with a diameter of roughly half an inch. The tube in the handle H is cut out at the top to give access to the spring S, and the bottom ends in a single-terminal brass plug M. The corresponding brass socket F on the lead L is shown in Fig. 2(b). The use of a plug and socket allows the whole prod/clip to be easily disconnected from the lead and replaced by a different sort of tool. The handle H fits into a rubber mould to provide insulation. The wall thickness of this mould will be about $\frac{1}{32}$in; the exact thickness being determined by the elasticity, as that part of the mould facing the spring S will be pressed in and out when the clip is opened and closed. The socket F is insulated by another rubber mould.

The insulation of the arm A is provided by ordinary sleeving or thin rubber. The diameter of the metal tubing of A must not be smaller than about $\frac{1}{8}$in. The decisive factor here is the thickness of the internal wire which must be sufficient to give adequate gripping action on the jaws, and also to counteract the tendency of the upper jaw J_2 to twist sideways under the weight of the tool and lead. The smallest usable wire diameter is $\frac{1}{32}$in, but best results are obtained with $\frac{1}{16}$in.

Some details of the construction of the jaws J_1, J_2 are also worth noticing. When closed, the end of the lower jaw J_1 should protrude about $\frac{1}{32}$in beyond that of the upper jaw J_2. This means that for an average opening of say $\frac{1}{32}$in the ends are in fact in line. This gives a good grip, and also ensures that the two jaws do not obscure each other. The inner part of J_1 is given a slight protruding curvature. This and the fact that J_2 is bent a little more than J_1 mentioned previously ensures a good grip on small objects. Finally, the internal edges of both jaws are given a set of fine teeth as in ordinary crocodile clips.

Method of Short Circuiting the Isolating Capacitor.—Figs. 3(a) and (b) show the construction of the more elaborate tool. This uses the same basic parts as in the simpler model, except that the ordinary lead and socket L is replaced by a coaxial lead ending in a container C. This houses the isolating capacitor I, the socket F, and a device to short out the capacitor I by simply rotating the lead L through 90° to 270°, relative to the handle.

Good connection between the two parts is secured by the plug M and socket F, and also by a split metal ring R which maintains contact between the metallized shielding of the upper part and the container C. This latter is in turn attached to the metal braid of the coaxial lead. Finally, the rubber mould of the handle overlaps the ring R and clasps the cylindrical surface of C, thus helping to ensure a firm mechanical attachment between the two parts.

A special half-insulated washer W_1 and the contact spring S_1 form the simple device which enables the isolating capacitor I to be shorted out when required. The spring S_1 is connected electrically to the lower end of the capacitor I, through gaps in two insulating washers W_2, W_3 which support the socket F and capacitor I. The top part of the spring S_1 is shaped in a similar way to the contact springs in miniature rotary switches. The half insulated washer W_1 is rigidly fixed under the plug M. When the two halves of the tool are assembled, the top part of the spring S_1 is in mechanical contact with the washer W_1 all the time, but electrical contact can be made only over the non-insulated half of the washer W_1.

The contact positions are identified by lines L_1, L_2 marked on the handle, and lead, such that when L_1 and L_2 are in line the isolating capacitor I is short-circuited. By rotating the lead in either direction through between 90° and 270° relative to the handle the capacitor I is replaced in circuit.

Method of Screening.—Proper screening of such a tool is very important when a.c. tests on high-impedance circuits are to be performed without introducing excessive hum or upsetting couplings. The use of the metal container C enables this to be done for the lead L without any difficulty. However, shielding of the rubber mould round the handle H and arm A is rather difficult as the shield must be pliable at least around the spring S. It has been found that the best method of screening is to cover the arm A and handle H with spiral wound wire preferably stuck to the surface. One end of the wire is threaded through a small hole in the mould on the handle H to make contact with the metal ring R and thence via C with the braid on the coaxial lead. The whole surface of the arm A and handle H is then painted with gold conducting paint, and, when this is dry, with several layers of insulating paint (such as "Hymeg" made by Berger). This ensures screening properties nearly as good as those provided by orthodox braided sleeving; and even prolonged movement of the shielding over the springs will not upset this screening.

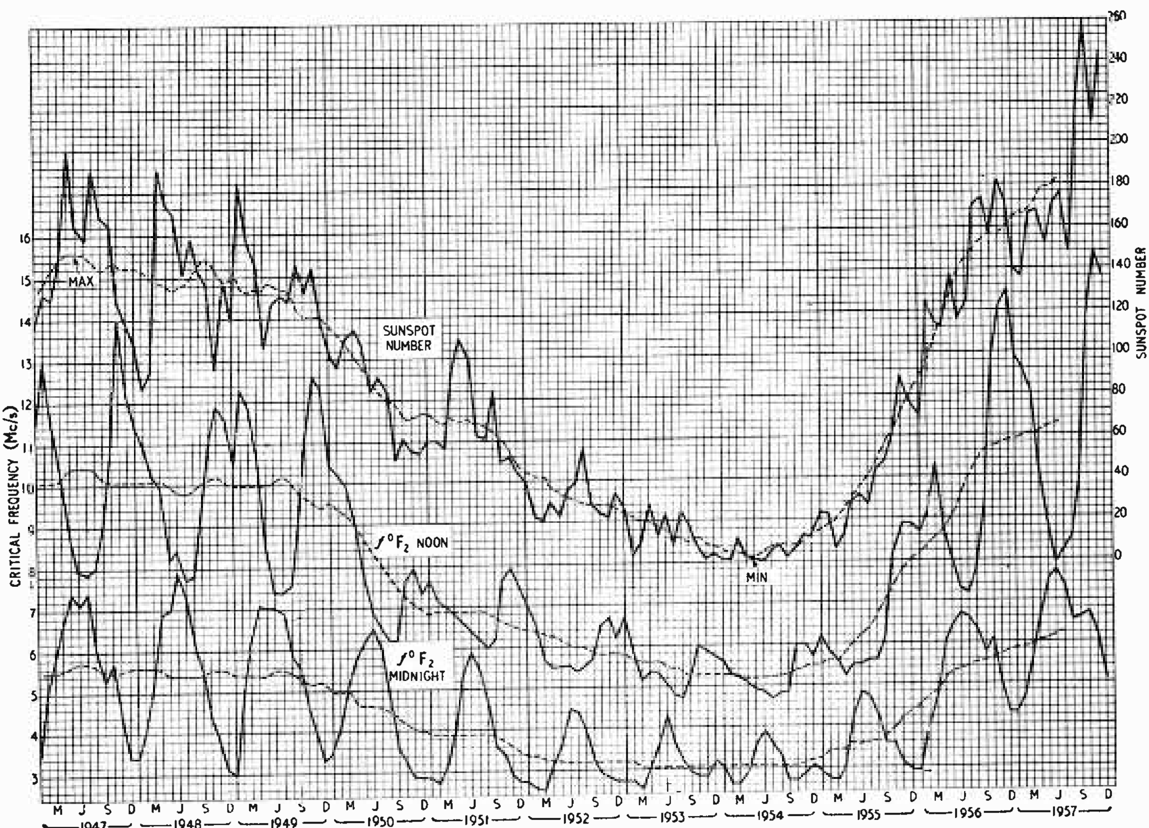
Ionosphere Review 1957

RECORD "HIGH" CONDITIONS

By T. W. BENNINGTON*

THE monthly average relative sunspot number—continuous records of which go back to January, 1749—has, prior to the present sunspot cycle, exceeded a value of 200 on only three occasions, in May, 1778, December, 1836, and May, 1947, which months were all near high sunspot maxima. During the present cycle the value of 200 was first exceeded in November, 1956, and during 1957 the provisional values for September, October, November, and December, were 218, 259, 211, and 244 respectively, the October value being the highest ever recorded. The "smoothed" sunspot number—determined from a twelve-month running mean of the monthly numbers—has never, prior to the present cycle, exceeded a value of about 159, but during every month of 1957 for which it is yet available it has been greater than this and, in fact, reached about 183 at the epoch June/July, 1957. The point of interest to radio engineers about all this is that it indicates that, during 1957, the solar activity has been extraordinarily high, and it would be expected, therefore, that as a result the ionization in the principal ionospheric layers would be much enhanced, and the usable frequencies for long-

*Research Department, British Broadcasting Corporation.



Variations in sunspot activity, with corresponding variations in ionospheric conditions, 1947—1957.

distance communication considerably higher than usual.

It may here be of interest to remark that the "relative sunspot number," which is internationally used as an index of the general solar activity, was instituted by R. Wolf, of Zurich, many years ago, and is derived from observations made at a number of different observatories. The relative number is deduced from these according to the formula:—

$$R=C\ (10G+N)$$

where R is the relative sunspot number, G is the observed number of sunspot groups, N is the total observed number of sunspots, and C is a factor which depends on the telescope used and on other factors affecting the observations. Thus the large groups, which are the most active areas, are suitably weighted as compared with the smaller spots, and the observations from different places are reduced to a common basis. These relative numbers, despite what may seem to be a somewhat arbitrary method of derivation, have been found to correlate well with terrestrial phenomena which depend upon the solar activity.

Course of the Sunspot Cycle.—The variations in solar activity since the last sunspot maximum, and its effects upon the F_2 layer ionization, as indicated by measurements of the vertical-incidence critical frequency of the layer, may be seen from the graphs. The sunspot numbers shown are those published from Zurich, except for the last 12 values, which are the provisional numbers obtained by the Royal Greenwich Observatory. The F_2 critical frequencies are those measured at the D.S.I.R. station, Slough. The full-line graphs are of the monthly values, and the dashed lines give 12-month running mean values, thus smoothing out the seasonal and other variations.

Since the last sunspot minimum in April/May, 1954, the sunspot activity has quickly risen to reach the unprecedentedly high values now prevailing. At the end of 1956 it was thought that the maximum would be a record high one, and that it might occur early in 1957, though, since future sunspot activity cannot be predicted with much accuracy, there was no certainty about this. Though the first of these anticipations proved correct the second did not: in fact, at the end of the year the activity—as indicated by the 12-month average sunspot number—was still rising. We must remember, though, that we can only know this value up to a time six months back, and, since it is from this quantity that the epoch of sunspot maximum is determined, this may still have occurred in 1957.

The average critical frequencies, it is seen, have increased by a factor of just over two since 1954, and, both at noon and midnight during 1957 were considerably higher than at last sunspot maximum. During the autumn the monthly mean critical frequency for noon reached remarkably high values, that of 15.4 Mc/s for November being an example. This would imply a monthly mean m.u.f. for noon of about 43 Mc/s, which would mean that on some days the m.u.f. would be above 50 Mc/s. Such very high m.u.f.s have, in fact, been observed to be occurring in practice. Thus, during 1957, the F_2 critical frequencies and m.u.f.s did indeed follow the rise in solar activity, to reach record high values.

Usable Frequencies.—Practical reception results clearly indicate the effect of the abnormally high solar activity upon radio propagation, the upper frequency limits for long-distance reception having been remarkably high. The highest frequency band for long-distance broadcasting—26 Mc/s—has been usable throughout the year, and the same applies to the 28-Mc/s amateur band. To take, as an example, the North Atlantic circuits, the highest frequencies receivable over these gradually decreased during the spring from the neighbourhood of 45 Mc/s to about 35 Mc/s in April. They further decreased to about 28 Mc/s in July, following on the summer decrease in daytime F_2 layer ionization in the northern hemisphere. By September they had increased again to the order of 40 Mc/s, to over 50 Mc/s in October, and to about 55 Mc/s in November. It is not meant, of course, that these high frequencies were receivable on every day, for, with the high solar activity, a considerable number of ionospheric disturbances occurred and on disturbed days the F_2 layer ionization was much reduced. But on undisturbed days they were often receivable during the periods mentioned, and provide interesting proof of the very high frequency limits for long-distance F_2 layer propagation at times of very high solar activity.

A further interesting example is given by reports of the reception of the Crystal Palace sound (41.5 Mc/s) and vision (45.0 Mc/s) channels at long distances. During the 1956 autumn and early winter the sound channel was occasionally received in Australia and the West Indies, and both channels were being frequently received in West, Central, and South Africa. In the spring of 1957 such reception was again frequent in Africa, but in the summer it became much less so. During October, November, and December, reception again occurred frequently in Africa, and was also reported from a number of places in Canada and the U.S.A. The vision channel was received in Australia in December. Reports from Johannesburg indicate that between 1000 and 1800 G.M.T. signals on the sound channel were obtained for the following approximate percentages of the time: January 2.0, February 23.4, March 59.3, April 61.8, May 22.2, June 14.4, July 10.3, August 8.2, September 22.2, October 47.4, November 28.0. Signals on the vision channel were received for considerably smaller percentages of the time, but their reception followed the same seasonal pattern, i.e., the peak periods being around the equinoxes. By vision channel reception it is not meant, of course, that good television pictures were obtained.

As for 1958, it appears possible that sunspot maximum will have occurred before the year begins and, thereafter, that the highest usable frequencies will start to decrease. But, since it is highly probable that this decrease will be a very slow one, we may expect little change in propagation conditions over various paths as compared with those during similar months of 1957. The daytime frequencies will of course decrease, and the night-time frequencies increase, from present values towards the summer, and next autumn they are unlikely quite to reach the present high values. But, so far as long-distance communication of all kinds is concerned, the highest frequencies actually allocated for the various services should be usable over one circuit or another throughout the year. And there is every probability that "quasi maximum" radio conditions will prevail throughout 1959 as well.

LETTERS TO THE EDITOR

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

Loudspeakers in Parallel

I WOULD like to reply to the two letters in the December 1957 issue commenting on the article "Loudspeakers in Parallel. Increase of apparent source size is not one of their advantages" (October issue).

Anyone who differs from Mr. G. A. Briggs on a subject like this has the dice heavily loaded against him but I will try my luck. As the title implies, the contribution was intended to draw attention to what I think is a contradiction of the obvious conclusion, and it was not intended to be a condemnation of paralleled units, for on almost every other score two units in parallel have advantages over a single unit.

Mr. Briggs agrees with me on the assumption that I intended that directional speakers are used, but strangely enough (and hence the article) I think the conclusions are valid for omni-directional sound sources. If I put two similar speakers up side by side and connect them in parallel I can hear only the nearer speaker. In short, the position of the virtual sound source is that of the nearer speaker, but the loudness is due to the resultant output of both speakers. This is true (I believe) irrespective of the spacing of the units. If anybody has tried this and finds that there are conditions in which it is not true I will be pleased to hear from them.

I heard Mr. Briggs' last demonstration at the Festival Hall and I noted that the sound source always appeared to be located in the nearer speaker, though I have no doubt whatever that the presence of the other speakers were advantageous in other directions. There is a simple but striking demonstration of the effect using a line source speaker which may have up to 20 similar loudspeaker units handling the same signal.

If this is laid down horizontally and the listener stands in front of it he will find that the apparent position of the sound source is that of the nearer speaker, i.e. the one directly in front of him, and that this moves along as he moves parallel to the source.

If the two units differ in the response, then the sound source is stretched; but other troubles, a ragged frequency response and a disembodied-voice effect, begin to appear. These effects get worse as the difference in response between units increases. The separation at which a balance is struck is a personal compromise.

One of the advantages claimed for spaced speakers is, as Mr. Briggs mentioned, the question of the reduction of standing wave patterns. I hope to document this aspect in the near future.

The letter from Mr. Barzilay is a more difficult problem. I think he is implying that there are conditions in which two loudspeakers appear larger than one, but as he does not state what these conditions are I cannot comment.

Rugby. J. MOIR.

Mr. Briggs comments:

I agree with Mr. Moir that in a small room the sound seems to come from the nearest speaker when two or three ordinary or semi-directional types are switched on, but I find that this effect can be largely overcome by facing the speakers obliquely towards a wall and listening to reflected sound.

As regards our last Festival Hall demonstration, we had four speakers spaced very widely apart on the platform, because this seemed to give us the nearest simulation of the actual orchestra. Again, I agree with Mr. Moir that perhaps one-third of the audience would place the sound in the speaker nearest to them; but I think the remainder of the audience sitting in the centre and at the back of the hall would find the sound coming from all four speakers, because the difference in distance would not affect the issue. I remember that we always sat at the back of the stalls for our listening tests at rehearsal, and I certainly got this impression. Actually, front and side seats are not really satisfactory for listening to loudspeakers. G. A. BRIGGS,

Idle, Yorks. Wharfedale Wireless Works, Ltd.

Tape Speeds

THERE are two comments that I think can usefully be added to "Free Grid's" interesting note, "Irritating Irrationalities," in your January issue. In this he commented on the curious fact that, throughout the world, supply voltages are rated in multiples of 11 and suggested that this derives ultimately from the 1.1 volts of the Clark cell. He then went on to discuss what he referred to as the "insane illogicality" of the standard tape speeds, $7\frac{1}{2}$, $3\frac{3}{4}$, $1\frac{7}{8}$ (and so on) in/sec now being used for magnetic recorders and surmised that this practice arose from successive halvings of an original tape speed of 30 in/sec. This is, of course, largely the case but, as so often happens, the truth is rather less simple and rather more interesting than it appears.

It is true that 30 in/sec was the speed generally used in this country and the U.S.A. in the middle and late 1940s but it was a very close approximation to the standard speed that had already been adopted in Germany. The German standard was naturally a metric one and it was, as "Free Grid" would have wished, a whole number; but what seems a little curious and does not appear to have been explained is why the precise value chosen was 77 cm/sec. I think that we can hardly blame the Clark cell in this case.

As regards the second point, I think that "Free Grid" will see on reflection that it is not always right to suppose that saneness and logicality require the use of specifications expressed in whole numbers. A cake recipe which called for $1\frac{7}{8}$ eggs would certainly be undesirable and equally a standard which implied a.c. motors with shafts rotating at 1,655 r.p.m. on a 50-c/s mains supply would be inconvenient. In the case of tape recording and reproducing machines, however, the tape is almost always friction driven by a spindle which must in any case have an "odd" diameter and it is difficult to see any practical advantage that would attach to the use of a speed of one instead of $\frac{15}{16}$th in/sec or of two instead of $1\frac{7}{8}$ in/sec.

In any case it must surely be accepted that if the inch-using countries were to have "sane and logical" tape speeds, expressed in whole numbers of inches per second, and if the metric countries were to be equally "sane and logical" in centimetres then we would not have international interchangeability and this would hardly be either sane or logical.

It is perhaps worth adding, "for the record" so to speak, that there was a period in the late 1940s when two slightly different versions of the same nominal tape speed existed side by side, that is to say 30 in/sec in U.K. and the U.S.A. and 77 cm/sec (or 30.16 in/sec) in the European countries. While not wholly irrational this was certainly irritating if only because of the differing durations of nominal half-hour recordings when made in one country and replayed in another. The first steps towards international standardization of the speed and other characteristics of magnetic tape recording were taken at a meeting of the representatives of a number of broadcasting organizations that was held in Berne in 1950. As a result it was agreed that all organizations would adopt the standard tape speed of 76.2 cm/sec (30 in/sec) and any slower speeds to be used in the future would be in a geometrical progression with a ratio 2:1. This has since been formally adopted as a world standard by the International Electrotechnical Commission so that the standard tape speeds are the same in all countries. In the inch-using countries they are expressed as 30, 15, 7½, 3¾, 1⅞ . . . in/sec and in metric-using countries as 76.2, 38.1, 19.05, 9.525, 4.7625 . . . cm/sec.

H. DAVIES,
London, W.1. B.B.C. Engineering Division.

Line Scan Ringing

MR. K. E. MARTIN'S letter in the December, 1957, issue notes early efforts in tuning leakage reactance of the television line scan transformer. For the record, my work on this feature resulted in the tuned line-scan/high-voltage transformer design incorporated in the Bendix Radio Division of Bendix Aviation Corporation's first commercial television receiver, Model 235M1, developed in 1947-1948 (marketed in 1948). This design employed tightly coupled primary/secondary windings, a high-build "narrow cam" tertiary. The core of the Bendix transformer was of powdered iron of the cartwheel-and-split-hub variety; this was prior to my investigation of ferrite cores in 1948 at the General Electric Company, resulting in the Model 77J1 transformer. The Bendix development is recorded in my notebooks remaining with Bendix Radio Research Laboratory in Baltimore.

A realization of the importance of the critical coupling of the tertiary and impedance relationships in the output circuit struck me forcibly at that time, as I noted the reduced driver and damper valve peak voltages resulting from correctly phased harmonic content. That the early Bendix coil was fairly in-tune was the basis of use with it of pressed-stem single-ended damper valves (operating at less than 2 kV anode-to-cathode), the first 6W4-GT diodes commercially available to Bendix supplied by National Union Co. This low-surge voltage introduction of the 6W4 to commercial use was followed by later insulation improvement with button-stem construction, and improved ratings.

The horizontal sweep-output valves initially selected were single-ended auto-radio output valves, two type 7A5, used in parallel. The later introductions of the G.E. 6AV5 and RCA 6AU5 were based on maintaining the driver surge at low levels, as results from harmonic reduction of the fundamental peak voltage at the driver plate. Retention of the transformer tuning allowed single-ended driver tubes to be upgraded from 50 deg sweep to 90 deg sweep as demonstrated with my paper presentation at the I.R.E./R.T.M.A. Fall Meeting at Syracuse, New York, in 1952, also emphasizing core "d.c. de-saturation."

Contemporary with my development at Bendix, independent work by R. B. Gethmann at the General Electric Company led him to devise a tuned TV transformer based on a closed, laminated core loop, one leg of which contained layer-wound primary and secondary coils, the h.t. overwind being a layer-wound tertiary coil mounted on the opposite leg and properly poled for additive fundamental voltage surge, tuned to minimize the primary voltage crest with harmonic adjustment. These tuned transformers were used in G.E.'s early post-war television receivers.

CHARLES E. TORSCH,
Chief Television Engineer,
Cleveland, Ohio, U.S.A. The Rola Company, Inc.

"Do It Yourself" Interference

THOUGH I did not view the television Children's Hour series on how to make a simple radio receiver, referred to by Douglas Walters in his letter in your December issue, I feel he is trying to "damp" the "wave" of youth's enthusiasm for scientific knowledge.

It is possible that in the years to come we may owe Gilbert Davey gratitude for several hundred additional engineers in the electronics industry, thanks to the spark of interest produced by a boy's "Do-it-yourself" radio receiver.

In the early nineteen-thirties, several of my young friends and myself were helped by our fathers and neighbouring friends with the gifts of radio junk, which to us at that time was more valuable than gold. My happiest days were spent winding a coil on an old ebonite former, with the end of the "cotton-covered" tied to the door handle, plus the frantic efforts to get my one-valver to work. This, with a valve that cast strange patterns on the wallpaper in the failing December light, and a neighbour, pipe in mouth, finding where I had erred, was true happiness.

Yes, those eleven-plus years of mine and young radio friends are long remembered. All served in radio during the second World War, and are professional radio men at the present time, thanks to a one-valve regenerative detector.

No! Douglas Walters, let's tolerate a few squeaks in our 'Ohms, to the furtherment of electronics.

PETER STARK LANSLEY,
Communications Officer,
Ministry of Transport & Civil Aviation.
Southampton (Eastleigh) Airport.

TV Whistle

IT would seem that the viewing of your correspondent, Mr. D. A. Thoms (January issue), has not yet been extended to a Peto Scott receiver. For some years now, these receivers have incorporated a direct drive type of line time base, which allows the use of a line output transformer core consisting of a single Ferroxcube rod. Most line time base whistle comes from the joins of the two halves of the closed loop core of the conventional auto transformer where, if the gap is not completely rigid, the magnetic effect of the alternating flux causes slight movement and hence the whistle. In the direct drive system, this gap is obviously non-existent and, in consequence, very little whistle indeed is produced.

BRIAN G. SCOTT,
Weybridge. Peto Scott Electrical Instruments, Ltd.

Optical Noise Filter

"STOPPING down" a lens limits its effective optical area. As only the centre portion is in use, this area of the lens in the human eye is more truly spherical. Objects lying in the same plane form images at the focal point (retina) more exactly than when subject to the distortion due to the less exactly spherical portion near the periphery of the lens.

You may say "why not wear two pin-holes instead of spectacles?" This would improve our vision if we were prepared to carry the odd arc lamp around to make up for a subsequent loss in illumination!

Colchester. E. A. SHAW.

SURELY the effect mentioned by your correspondent T. G. Clark in the January, 1958, issue, namely, the improvement in clarity of an object when viewed through a small aperture, is due to the increased depth of focus thus obtained. This is because the small aperture permits only those rays which are close to the axis of the eye's lens to be refracted.

If the rays farthest from the axis are excluded by the introduction of a small aperture, the image formed by the remaining rays on the screen is clearer, although still out of focus, and much dimmer.

This is similar to the "pin-hole camera effect," and makes the eye less dependent on its lens for focusing.

This would seem to explain the apparent improvement in television picture contrast and resolution when viewed through a small aperture, but the "noise filter" effect is not so obvious, since the pin-hole acts as an attenuator rather than a filter.

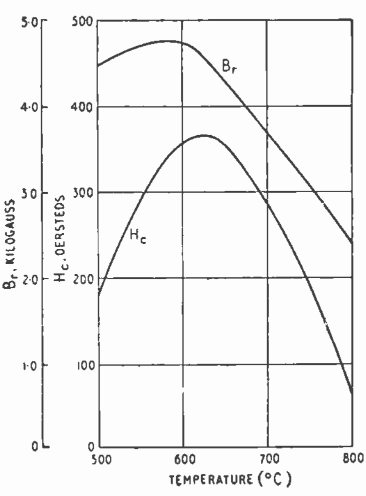
The "reality" of a television picture is increased when viewed through *one eye* only, due to the fact that one sees everything in two dimensions, and a 2-D picture therefore appears more "real." This could partly explain the improvement noted.

New Malden, Surrey. DAVID M. LINDSLEY.

Technical Notebook

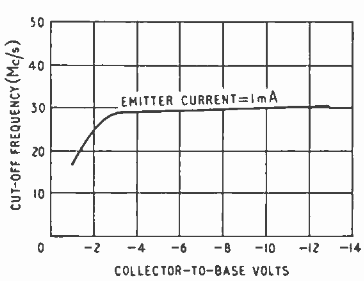
New Potting Compound said to have good electrical properties and high resistance to mechanical shock can be formed *in situ* by mixing castor oil with an organic isocyanate made by I.C.I. under the name Suprasec. The result of the chemical reaction is an amber-coloured opaque material which is rather like rubber except that it does not bounce. The lack of bounce when a potted electronic unit is dropped on the floor is somewhat alarming, but all the shock is said to be taken up by the material. Useful compounds such as flexible and rigid foams, soft and hard rubbers, lacquers, insulating compositions and adhesives can also be made *in situ* by mixing other polymeric reactants with the isocyanates. It is possible, for example, to fill awkwardly shaped cavities with foams or other materials, say, for insulating purposes, simply by pouring in the appropriate quantities of the two chemicals.

Thin Wire Permanent Magnets of only 5 mils in diameter have been cold drawn from a ductile magnet alloy called Cunife by I. L. Cooter and R. E. Mundy of the American National Bureau of Standards. Normally, of course, most commercial permanent magnet alloys have to be cast or sintered into the required shape because of their hard and brittle nature. Cunife, however, can be cold worked; and even if this is done to the extent of affecting adversely the magnetic properties of the material the characteristics can be substantially improved again by subsequent heat treatment. Values of coercivity, retentivity and maximum energy product for various diameters of the cold-drawn and heat-treated thin wires are given in the December, 1957, issue (Vol. 59, No. 6) of the *Journal of Research of the National Bureau of Standards*. As an example, the graph shows how the coercive force H_c, and residual induction, B_r, of 0.005-in diameter wire magnets vary with different temperatures of heat treatment. The composition of Cunife, incidentally, is 60 per cent copper, 20 per cent nickel and 20 per cent iron.



Magnetic-Line Propagation along the earth's field lines and passing well outside the usually accepted limits of the ionosphere has for some time been postulated for audio frequency "whistler" atmospherics (see *Wireless World* for July 1953, p. 338). Recently such propagation has been demonstrated for ordinary radio waves by Stanford University, according to a report in *Electronics Business Edition* for December 10th, 1957. A pulse-coded signal transmitted on a frequency of 15.5 kc/s from Annapolis in Maryland was received twice at Cape Horn: once by ordinary ionospheric propagation and the second time 0.7 second later and 10 to 30 dB weaker by "whistler" magnetic-line propagation.

Drift Transistors are high-frequency types, basically of alloyed construction, in which the transit time of the current carriers is reduced (and hence the cut-off frequency raised) by a "built-in" accelerating electric field. This field is produced by a special graded distribution of the impurities in the base region achieved during manufacture. As well as accelerating the current carriers, it also tends to reduce the collector capacitance, while the high average density of impurities in the graded base tends to give a low value of base resistance—both useful features for high-frequency operation. The alpha cut-off frequencies obtained are usually of the order of tens of megacycles. As an example, the new RCA drift transistors 2N370, 2N371 and 2N372 have an alpha cut-off frequency of 30Mc/s in the common-base connection (see characteristic). The 2N370 and 2N372, which are intended for r.f. amplification and r.f. mixing respectively, will give a maximum power gain of 17dB at 20Mc/s in typical operation in a common-base circuit (or 26dB at 10Mc/s). The 2N371 is intended for use as an r.f. oscillator for frequencies up to 23Mc/s. All three types incorporate shielding to minimize capacitance between leads and coupling to adjacent components. This is provided by a fourth lead situated between the collector and base leads and connected internally to the metal case.



Sensitive Displacement Transducer, designed by Salford Electrical Instruments for measuring small changes in radii of curvature, will detect movements as small as 2.5-0-2.5 thousandths of an inch. It is an electromagnetic type of transducer. A central stylus controls the position of a magnetic armature disc which is mounted in a gap between two pairs of coils. Each pair of coils is wound as a transformer and mounted in a high-permeability magnetic pot core. A constant alternating current is arranged to flow in the primary winding of each transformer and the output of the differentially connected secondary windings is fed to the moving coil of a dynamometer indicating instrument. Any movement of the armature disc causes a corresponding change in the mutual inductance of the coils, with a resultant increase or decrease in the current to the indicating instrument. A battery of 60 of these transducers is being used in the Royal Aircraft Establishment's new wind tunnel at Bedford as part of an automatic safety check on the strain in the steel plates which form the throat of the tunnel.

Variable Star Detector, using a flying-spot scanner is described by J. Borgman in *Philips Technical Review*, Vol. 19, No. 4. Using a partially silvered mirror, the light beam from the raster of the scanner is split into two parts which, after being focused, separately scan two negatives photographed at different times of the same region of the sky. The resulting transmitted images are then focused on to two photo-multipliers. The signals from these are subtracted and used to intensity-modulate the beam of an ordinary television c.r. tube. The sweep voltages of the picture tube and flying-spot c.r.t. are synchronized. Where the two negatives are different the signals from the two photo-multipliers will not be the same, and, when subtracted, will thus produce a mark on the picture tube corresponding to the position of the star. This will happen where the image of a star of variable luminosity is different on the two negatives owing to their different times of exposure. This provides a more rapid and certain method of variable star identification than the similar viewing by eye of a superposition of negative and positive, or viewing the rapid interchange of two photographs (blink microscope) where intensity changes will show up as changes in image size.

Transparent Magnetic Oxides known as rare-earth-iron garnets, permitting the internal magnetic domain structure to be seen with a polarizing microscope, have been discovered at the Laboratoire Electrostatique et de Physique du Metal of the Institute Fourier in Grenoble, France, and independently at the Bell Telephone Laboratories, U.S.A. Most magnetic materials are, of course, opaque to light and their internal magnetic structure is not visible. The manner in which magnetic domains are oriented within them has been inferred from reflection of polarized light by their surfaces or by delineating domain boundaries at these surfaces with colloidal magnetic oxides. Yttrium-iron garnet is the most completely studied member of the new garnet family. It has a Curie temperature of 545°K, as compared with 848°K for magnetite, and a spontaneous magnetization at zero temperature. Of great interest is the fact that it contains magnetic ions with but a single valence. Both x-ray and neutron diffraction studies have shown clearly that, unlike the ferrites, the interactions between identical magnetic ions wholly occupying two different crystallographic sites are responsible for ferrimagnetism in the garnet structure. In yttrium-iron garnet the width of the ferrimagnetic resonance absorption lines at 9,300 and 24,000Mc/s depends on crystallographic direction. Line widths of only 0.8 oersted were observed in thin discs at 10,000Mc/s, when the temperature was held at 540°K. These line widths increased with decreasing temperature and passed through peak values of several hundred oersteds between 65°K and 4.2°K. A polarized light beam passing through the transparent magnetic domains in rare-earth-iron garnets has its plane of polarization rotated in one direction in one domain but in the opposite direction in an adjacent and oppositely magnetized domain. This Faraday rotation is wavelength-dependent and amounts to several degrees per mil of thickness. It makes the domains within the crystals clearly visible. The internal domain structure can, therefore, be studied over a wide range of temperatures and magnetic field conditions. Thus, it has now become possible to correlate Faraday rotation in a magnetic material with spectroscopic data over a broad temperature range.

Hall-Effect Compass described by I. M. Ross, E. W. Saker and N. A. C. Thompson in the *Journal of Scientific Instruments* for December, 1957, depends on the voltage developed across a crystal of indium antimonide when a steady current is passed through it in the presence of the earth's magnetic field. The voltage output passes through maxima and minima as the crystal is rotated in azimuth and can be read on a galvanometer. The principle was first demonstrated by Righi over 70 years ago, using bismuth, but the recent emergence of materials like germanium with much greater Hall efficiency has made it a more practical possibility. Where temperature is not important germanium does, in fact, give the best voltage output, but indium antimonide gives better power output and sensitivity. The compass actually consists of a small slice of InSb crystal about 5-10 mils in thickness with electrodes electroplated on the edges. This is mounted in resin between Permalloy C pole-pieces, into which are screwed two 12-inch "concentrator" rods of the same high permeability material for collecting the earth's field and increasing the power output. With a current of 1 amp passing through two of the electrodes on the crystal, a 1° deflection from E-W orientation gives an open circuit voltage of 0.12 mV across the other two electrodes. The device is not very suitable for a direct-reading compass because of ambiguities in the readings, but has possibilities for null indication and, arising out of this, for servo operation, in which the compass card is automatically kept in correct alignment, and for automatic steering of small craft.

Multi-stable Transistor Circuits, using direct-coupled combinations of n-p-n and p-n-p transistors, have been devised by M. J. Wier, of Illinois University. The design principles are the same as used for bi-stable circuits and are described in D.S.I.R. unpublished report PB 122983*.

Half-Century Time Constant.—The insulation resistance of the 1-μF plastic film dielectric capacitors mentioned in our December, 1957, issue (p. 595) was given incorrectly as 1.5×10^9 ohms. It should, of course, have been 1.5×10^9 *meg*ohms.

The Tecnetron is a new French semiconductor device said to be capable of amplifying frequencies up to 1,000 Mc/s. Developed by M. Teszner at the National Centre of Telecommunications Studies, it consists of a 2-mm germanium rod, 0.5 mm in diameter, and has a narrow neck in the middle which is surrounded by a tiny ring of indium. Current passed from one end of the rod to the other can be controlled by a signal applied to the indium electrode. The action is said to depend on an internal field, and the device appears to be somewhat similar in its mode of operation to the field-effect transistor.

* Obtainable from the Lending Library Unit of the D.S.I.R., 20, Chester Terrace, Regent's Park, London, N.W.1.

Pulse-Type Frequency Measurement

By J. C. MULLER,* B.Sc.(Eng.)

Apparatus for the Checking of Crystal Oscillators

PROBABLY the most accurate method of frequency measurement involves comparison of the unknown or test frequency with some known standard and counting the resultant low-frequency beat. This takes place either by provision of a fundamental standard frequency of the same value as the test frequency, or through suitable translation of either the test or the standard frequency to provide the required beat.

The general method of multiplication of frequencies is through harmonic generation, for which several well-known methods exist, all involving deliberate distortion of the fundamental and then selective amplification of the required harmonic frequency.

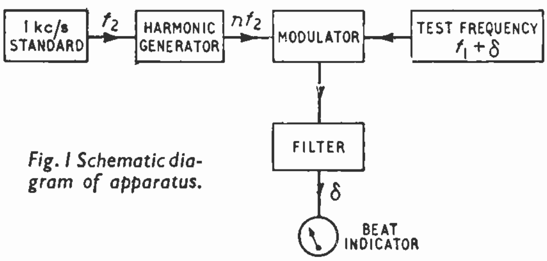


Fig. 1 Schematic diagram of apparatus.

A well-known frequency generating equipment employs 4 kc/s pulses generated by means of a saturable reactor[1]. Harmonics up to the 27th and 28th have a substantially constant amplitude, giving rise to a highly efficient generator.

During discussions about the use of low-frequency counters it has been suggested that a method of using a 1-kc/s pulse generator for frequency measurement be employed.

The project was first investigated as a possible means of comparing, approximately, known crystals against a standard. For example, suppose that a crystal has a frequency known to be $f_1 \pm \delta$, where δ is a very small deviation (fraction of 1 cycle per second), and it is required to determine δ. If this frequency is mixed with a standard frequency f_1 a beat of frequency δ will result, which can be counted, visually or by means of a low-frequency counter. The standard f_1 may be derived as an nth harmonic of a suitable low-frequency standard f_2, which means that a range of standard frequencies nf_2 is available.

In the particular case, all test frequencies of interest were integral multiples of 1 kc/s which was adopted as a suitable fundamental. The mixing process produces a series of modulation products, but, provided the mixer is followed by a suitable low-pass filter, only δ will appear in the output. Fig. 1 shows the proposed set up.

Harmonic Generator.—The frequencies of interest covered from 60 kc/s to 600 kc/s, a useful band in carrier telephony, therefore involving harmonics up to and including the 600th. From the Fourier series for a rectangular wave as shown in Fig. 2:—

$$\text{Average value } A_v = \frac{1}{T}\int_0^T F(t)\,dt \quad = \frac{Ad}{T}$$

Amplitude of the nth harmonic

$$C_n = 2A_v \left[\frac{\sin \frac{n\pi d}{T}}{\frac{n\pi d}{T}} \right]$$

Plotting C_n against the harmonic number results in the graph shown in Fig. 3. This shows that a rectangular wave of given width and repetition period contains harmonics only up to, but excluding n_0 where n_0 is the value for which $C_n = 0$.

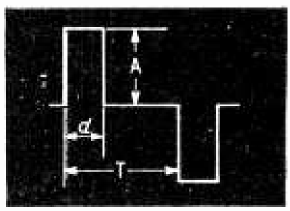


Fig. 2 Rectangular waveform.

Calculation showed that at a pulse repetition frequency of 1 kc/s a rectangular pulse of 1 μsec duration is required to give a reasonable performance at 600 kc/s.

Initially a saturable reactor was used to generate the pulse. This leads to a very simple circuit but it proved unsatisfactory for the short pulse required.

A convenient method proved to be by means of a delay line[2]. It can be shown that a wave travels along a transmission line with a finite velocity given by $\frac{1}{\sqrt{LC}}$ where L and C are the inductance and capacitance per unit length of the line. Any wave impressed on a line will therefore take a finite time to travel a certain distance or will reach the far end after a finite delay. If the wave is reflected at the far end and the line is loss-less, it will reappear at the near end after a time equal to twice the delay. If the required delay time exceeds a

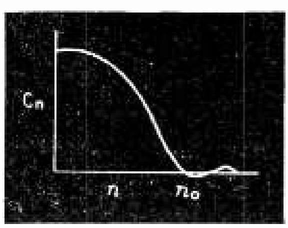


Fig. 3 Harmonic amplitude plotted against harmonic number.

*G.E.C. Telephone Works, Coventry.

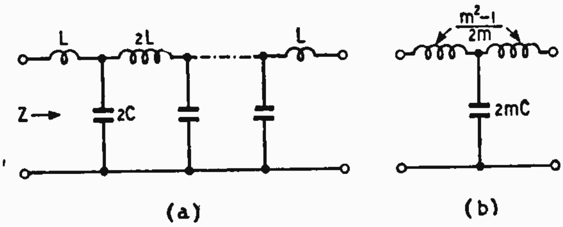


Fig. 4 Low-pass filter as a delay line.

small fraction of one microsecond, however, the cable becomes inconveniently long; thus, e.g. a polythene cable for a 1 μsec. delay is 200 metres long. In these cases lumped parameter lines are used, the simplest being a low-pass network. For the network shown in Fig. 4(a) it can be shown that

$$Z = \sqrt{\frac{L}{C}}\left(1 - \frac{\omega^2}{\omega_2^2}\right)^{\pm\frac{1}{2}}$$

according to whether the termination is mid-series or mid-shunt.

Phase shift in the pass band is

$$B = 2n \tan^{-1}\left[\frac{\omega_2^2}{\omega^2} - 1\right]^{-\frac{1}{2}}$$

$$= 2n \sin^{-1}\left(\frac{\omega}{\omega_2}\right)$$

where ω_2 = critical angular frequency = $\frac{1}{\sqrt{LC}}$

n = number of complete sections.

At low frequencies the following approximations can be made:

$$Z \doteq \sqrt{\frac{L}{C}}$$

$$\text{and } B \doteq \frac{2n\omega}{\omega_2} = \omega 2n\sqrt{LC}$$

The delay $= \frac{dB}{d\omega} \doteq 2n\sqrt{LC} = \sqrt{L_t C_t}$

where L_t and C_t are the total inductance and capacitance. The phase curve $\sin^{-1}\left(\frac{\omega}{\omega_2}\right)$ is concave upwards so that $\frac{dB}{d\omega}$ increases continuously with frequency. A more linear phase characteristic and hence a more constant delay is obtained using the m-derived structure, as shown in Fig. 4(b), with $m = \sqrt{1.5} = 1.23$.

To produce the pulse the line is discharged through some form of switch operating at the required repetition rate. In this case a small thyratron was used. The thyratron is normally biased to a suitable voltage and is non-conducting, with the anode at supply voltage. A trigger voltage is applied to the grid and on reaching the set value triggers the valve. A heavy current flows resulting in a large volt drop across the anode resistor. The anode voltage decreases to the point where the valve cuts off again and abruptly rises back to supply level. The pulse-forming network may ideally be represented as in Figs. 5(a) and 5(b).

Fig. 5(a) represents the condition during charging of the line, i.e. with the thyratron non-conducting. Switch S is open and point a is at supply potential V_s. The line charges through resistance R to this potential.

When S is suddenly closed due to the thyratron conducting, a circuit is formed with the transmission line charge and resistance R, equal to the characteristic impedance of the line, in series, resulting instantaneously in equal volt drops across R and Z equal to $\frac{V_s}{2}$. The voltage wave of magnitude $\frac{V_s}{2}$

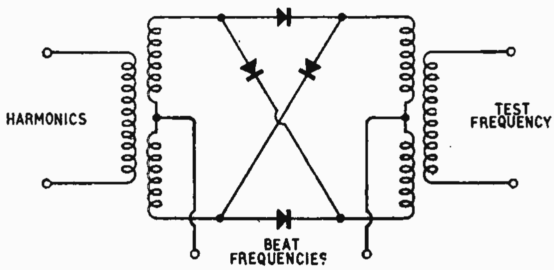
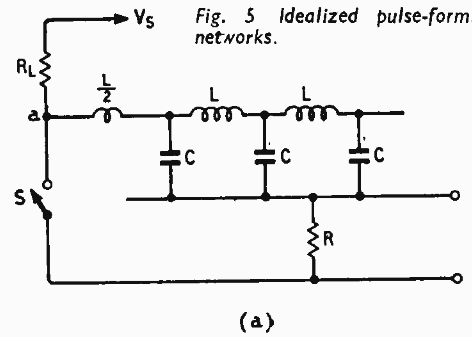


Fig. 6 Modulator circuit.

travels along the line and is reflected at the unterminated end, suffering a reversal in sign. After a time $2\frac{dB}{d\omega}$ it reappears at the input end and cancels the voltage across R. The result is that a voltage of magnitude $\frac{V_s}{2}$ appears for a period $2\frac{dB}{d\omega}$ across R and is then suddenly cancelled. This happens once per cycle of trigger voltage. With a well-designed delay line, and provided the repetition period is long compared to the de-ionizing time of the thyratron, near perfect rectangular pulses can be generated.

In order to obtain a beat of sufficient amplitude it was found necessary to amplify the pulse appreciably. This presented a problem since the pulse generated had an amplitude of approximately 10 volts. Further, due to the unequal amplitudes of the harmonics, the low-order harmonics



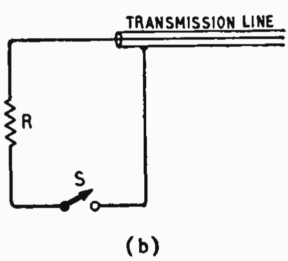


Fig. 5 Idealized pulse-forming networks.

tended to overload the modulator, resulting in poor mixing at the high frequencies. It was, therefore, decided to introduce some form of band-or low-pass filter between the harmonic generator and the modulator.

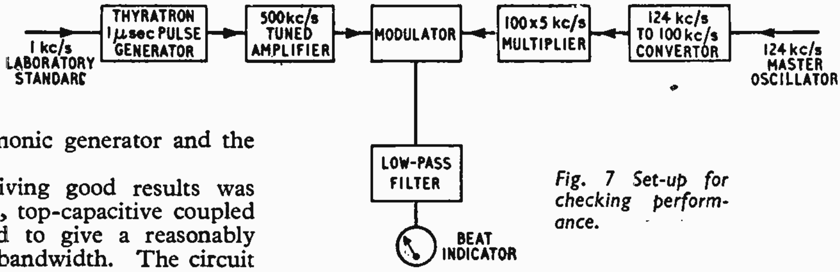


Fig. 7 Set-up for checking performance.

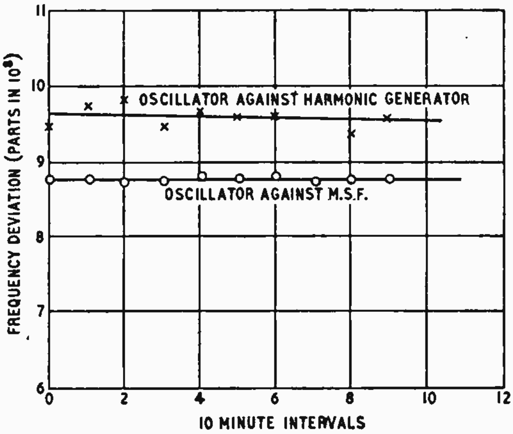


Fig. 8 Curves showing oscillator deviation measured against MSF standard frequency transmissions (2.5 Mc/s) and 1 kc/s pulse harmonic generator.

The simplest network giving good results was found to be a double-tuned, top-capacitive coupled circuit. This was adjusted to give a reasonably square response of 20 kc/s bandwidth. The circuit may either be tunable to cover the required frequencies, or a number of tuned circuits may be switched to cover the range.

The output from the tuned circuit was amplified approximately 50dB by means of an aperiodic amplifier giving an output voltage of some 50 volts peak.

The Modulator.—Fig. 6 shows the germanium diode lattice modulator fed through two balanced transformers as used in the apparatus. A variation introduced was to feed the harmonic and test frequencies into the two opposite ends of the modulator and obtain the beat frequencies at what is normally the carrier input terminals.

The beat frequency required will be that between the test frequency and the nearest harmonic of the standard. It will therefore be the lowest frequency present in the modulator output. A low-pass filter with a cut-off frequency of 15 c/s was inserted in the output and a 300-0-300 microammeter was used as a beat indicator.

Performance.—To assess the performance of the apparatus, it was used to measure the frequency deviation of a 500 kc/s test frequency. The latter was derived from a 124 kc/s temperature-controlled crystal master oscillator by means of a 124 kc/s to 100 kc/s converter followed by a multiplier. The oscillator was first checked against the 2.5 Mc/s standard frequency transmitted from MSF Rugby, by means of a frequency measuring apparatus[3]. Immediately afterwards, the test oscillator was checked against the apparatus described (Fig. 7). The 1 kc/s standard frequency was supplied from a laboratory standard using a temperature-controlled crystal oscillator.

The accompanying graphs, Fig. 8, show typical readings obtained of frequency deviation from 500 kc/s over a 90 minute test period. It can be seen from the lower graph that the test oscillator maintained a constant deviation of 8.8 parts in 10^8 below 500 kc/s. The upper graph shows the corresponding readings obtained from the pulse apparatus. There is a certain amount of scatter but this does not exceed 3 parts in 10^9 about the mean. It is known that the scatter of the 1 kc/s standard does not exceed 1 part in 10^9 about the mean.

The apparent average discrepancy between the readings obtained by the two methods is actually the deviation of the 1 kc/s laboratory standard above the nominal value.

Errors are involved in the measurements due to inaccurate counting of the beat. This was done visually and timed by means of a stopwatch. It is often difficult to obtain a smooth and defined beat due to noise or small disturbances on the supplies. The author tried to minimise errors due to these factors by means of voltage supply regulation and secondly by counting each beat when the pointer passed the zero position on the scale in one direction only. Furthermore, the beats counted were of sufficient number and length of time to make small timing errors insignificant. It was estimated that these errors did not amount to more than 0.5 parts in 10^9.

The scatter observed in the readings could possibly be considerably reduced by more efficient triggering of the thyratron. In the present set-up a sinusoidal trigger voltage was used, although an attempt was made to minimize the possible variation in triggering instant by using a trigger voltage of magnitude at least twice the negative bias on the thyratron, thereby ensuring triggering during the steep rise time of the wave. However, a substantial improvement is likely by using a 1 kc/s input that has been squared, differentiated and clipped. This should also tend to reduce any random noise component which might be modulating the output frequency. Another possible improvement is to produce the pulse by means of a blocking oscillator pulse generator.

In conclusion, the author would like to thank Mr. Doherty of the G.E.C. Applied Electronics Laboratory, Coventry, for supplying the thyratron pulse generator.

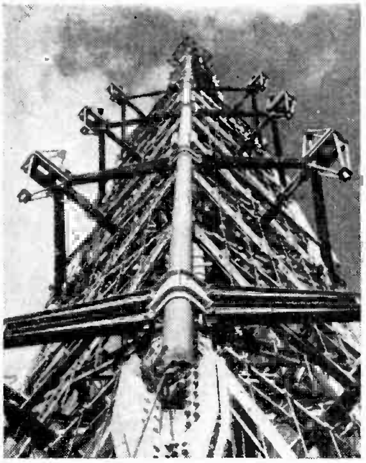
REFERENCES

[1] "Magnetic Generation of a Group of Harmonics" by Peterson, Manley and Wrathall, *B.S.T.J.* October, 1937.

[2] See for example "Radio and Radar Technique" by A. T. Starr (Pitman).

[3] "Testing Precision Oscillators" by M. P. Johnson, *Wireless World*, April 1955.

U.K. TELEVISION



Part of the B.B.C. Crystal Palace aerial which consists cf 8 tiers, each cf 4 dipoles, the lowest tier being at a height of 350 feet and the highest at 505 feet. The aerial was designed by Marconi's and the tower built by B. I. Callender's.

THE recent publication of the annual reports of both the B.B.C. and I.T.A., and the coming-of-age of television in this country, make it opportune to review the two services.

First, as befits the elder, the B.B.C. With the opening of three more permanent stations (Sandale, Isle of Man and Londonderry) during December and the completion of the permanent aerial at Crystal Palace, the coverage of the B.B.C. television service at the end of the year exceeded 98 per cent of the country's 50 million population.

It is hoped in due course to increase the coverage still further, and to this end additional stations are being planned for the Dover area, the Orkneys and Peterborough. As can be seen from the coverage map on this page, this still leaves large tracts of the country outside the service area, but for geographical reasons the task of adequately covering these sparsely populated areas is extremely difficult. It may well be that the B.B.C. will have to resort to "fly power" automatic relay stations such as are used in Italy.

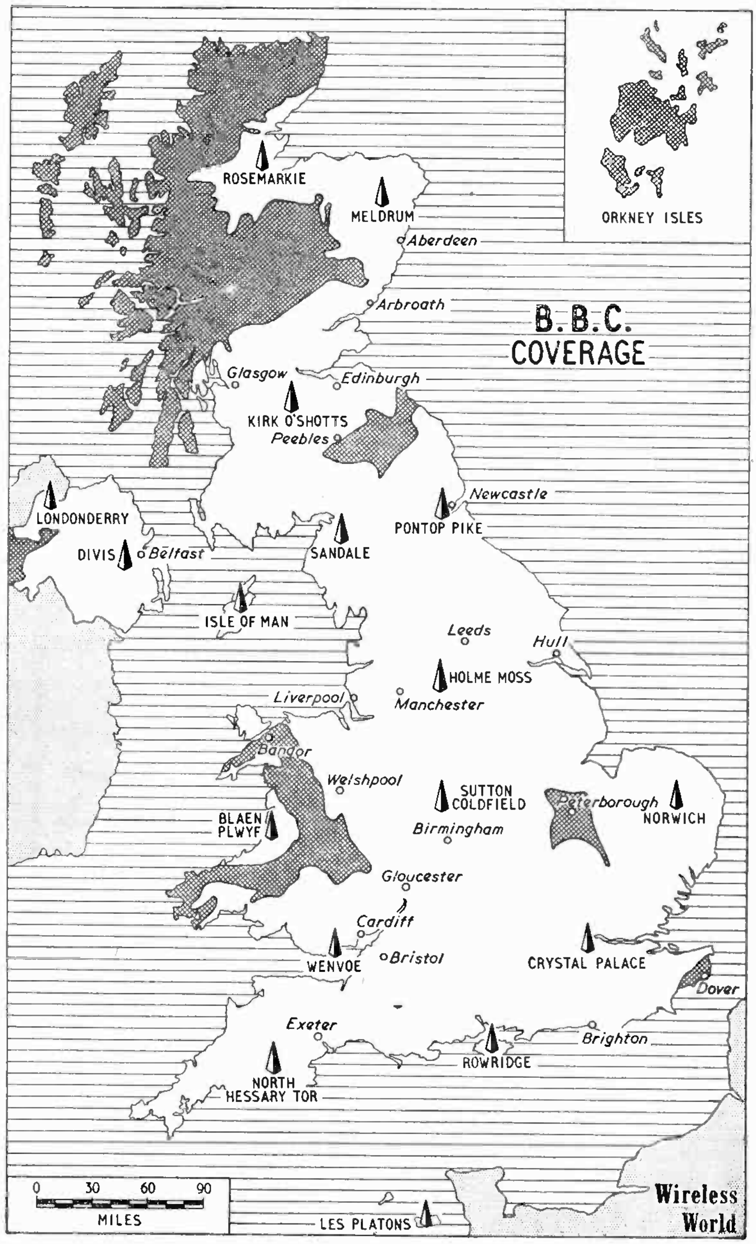
In addition to the stations already mentioned, the past year has seen the opening of permanent low-power stations at Rosemarkie and Blaen Plwyf and an improvement in the output power of the Norwich transmitter. This, incidentally, will be increased still further in the spring.

The vision signal radiated in Northern Ireland has in the past suffered to some extent because the Divis station has had to rely on the reception of the Kirk o'Shotts transmissions for re-radiation (sound is

B.B.C. STATIONS

		kW	
Channel 1 (45.00 Mc/s vision, 41.50 Mc/s sound)			
	Crystal Palace, London	200	V
	Divis, N. Ireland	12	H
Channel 2 (51.75 Mc/s vision, 48.25 Mc/s sound)			
	Holme Moss, Yorks.	100	V
	N. Hessary Tor, S. Devon	1–15	V
	Rosemarkie, Inverness.	1	H
	Londonderry, N. Ireland	1	H
Channel 3 (56.75 Mc/s vision, 53.25 Mc/s sound)			
	Kirk o'Shotts, Lanarks.	100	V
	Rowridge, Isle of Wight	1–32	V
	Norwich	1–10	H
	Blaen-plwyf, Cardigan.	1	H
Channel 4 (61.75 Mc/s vision, 58.25 Mc/s sound)			
	Sutton Coldfield, Warwicks.	100	V
	Meldrum, Aberdeen.	4–17	H
	Sandale, Cumberland	16	H
	Les Platons, Channel Islands	1	H
Channel 5 (66.75 Mc/s vision, 63.25 Mc/s sound)			
	Wenvoe, Glam.	100	V
	Pontop Pike, Durham	12	H
	Douglas, Isle of Man	1	V

Effective radiated power (peak white vision) is given. Where a directional aerial is used both max. and min. e.r p. are shown.
V = Vertical polarization.
H = Horizontal polarization.

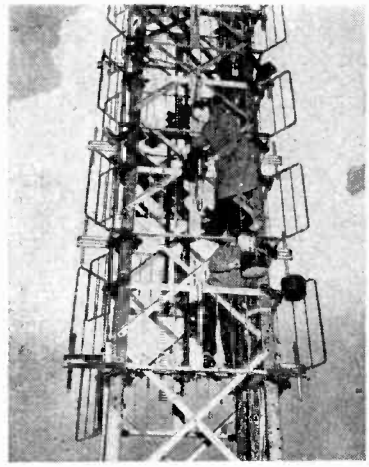


sent by line). To overcome the difficulty the B.B.C. has set up a station in the Isle of Man where signals from Holme Moss are received and relayed by a u.h.f. link to Divis.

The B.B.C. television service is now radiated by 18 stations including the temporary Brighton transmitter not shown on the map.

Now, to turn to the younger, the I.T.A.—not yet three years old. To forestall any criticism it should be pointed out that the I.T.A. coverage map is not strictly accurate as an end-of-the-year survey. It was not until January 14th that the St. Hilary station came into service, but it was originally planned for December 17th, and was in fact operating experimentally from that date. The opening of this station to serve an estimated population of over three million brings the total number of people within the service area of the six transmitters to about 38 million (76% of the population).

Within the service areas of the first five I.T.A. stations there are 4.75M homes with receivers capable of receiving both the B.B.C. and I.T.A.



Constructing the Channel 10 aerial installed by Marconi's for the St. Hilary I.T.A. station. It has a gain of 13 giving a vision e.r.p. of 200 kW. The engineers are seen here fitting anti-icing shrouds to the dipole supports.

St. Hilary is the second station to be opened in 1957, the other being Black Hill. Both these stations were to have novel aerials, but unforeseen technical difficulties in the system designed for St. Hilary necessitated further development work, and it was therefore decided by the Authority that in order to get the station on the air as soon as possible a more conventional type should be installed. The Black Hill aerial is unusual in that the elements are located centrally within the 750-ft mast and radiate through the openings in the lattice steel structure, thus reducing wind loading.

The I.T.A. plans for 1958 include the opening of the Chillerton Down, Isle of Wight, station and a North-Eastern transmitter.

References

"Annual Report and Accounts of the B.B.C., 1956-57" (Cmnd. 267). H.M.S.O. 6s.

"Independent Television Authority Annual Report and Accounts, 1956-57." H.M.S.O. 2s 6d.

I.T.A. STATIONS

	kW	
Channel 8 (189.75 Mc/s vision, 186.25 Mc/s sound)		
Lichfield, Staffs.	200	V
Channel 9 (194.75 Mc/s vision, 191.25 Mc/s sound)		
Croydon, London	120	V
Winter Hill, Lancs.	100	V
Channel 10 (199.75 Mc/s vision, 196.25 Mc/s sound)		
Emley Moor, Yorks.	10-200	V
Black Hill, Lanarks.	65-475	V
St. Hilary, Glam.	200	V

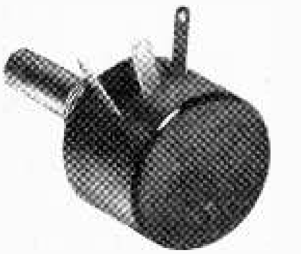
Effective radiated power (peak white vision) is given. Where a directional aerial is used both max. and min. e.r.p. are shown.
V = Vertical polarization.
H = Horizontal polarization

Manufacturers' Products

NEW ELECTRONIC EQUIPMENT AND ACCESSORIES

Midget Wire-wound Potentiometer

A NEW miniature, Type MW, wire-wound potentiometer measuring only ⅞in in diameter and 1⅛in deep has been introduced by the Reliance Manufacturing Co. (Southwark), Ltd., Sutherland Road, Higham Hill, Walthamstow, London, E.17. The new model has a ⅜in diameter fixing bush threaded 32 t.p.i., and a ¼in diameter spindle with a rotation of approximately 285°.



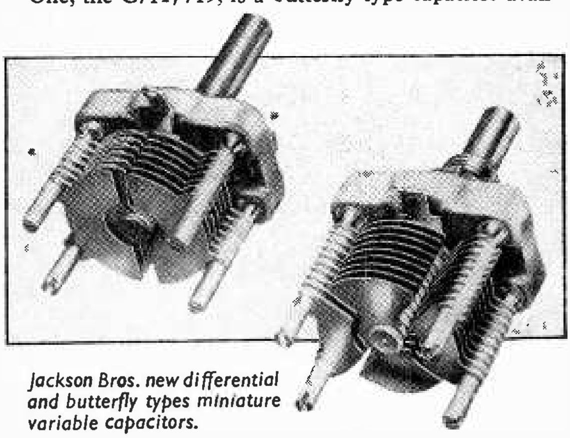
Reliance miniature Type MW wire-wound potentiometer.

Resistance values range from 5Ω to 50kΩ, the latter an exceedingly high value considering the small size of the potentiometer. The resistance tolerance is ±5% for potentiometers over 100Ω and ±10% for those below 100Ω and the rating is 1 watt with the whole element uniformly loaded. A difference of 500 V d.c. is the maximum permissible between spindle and track. The price is 5s 4d for potentiometers of 5Ω to 10kΩ, 6s for 10kΩ to 25kΩ and 7s 6d over 25kΩ and up to 50kΩ.

Miniature Variable Capacitors

THE illustration shows two new miniature variable capacitors recently added to the range made by Jackson Bros. (London), Ltd., Kings Way, Waddon, Surrey. Each is assembled on a single ceramic front plate measuring 1.187×0.937in.

One, the C711/719, is a butterfly type capacitor available in capacitance up to 65pF each section with 0.015in air gaps and up to 15pF each section with 0.045in gaps. The other, the C701/709, is a differential type with capacitance up to 150pF each half with 0.015in air gaps and up to 30pF each half with 0.045in air gaps.

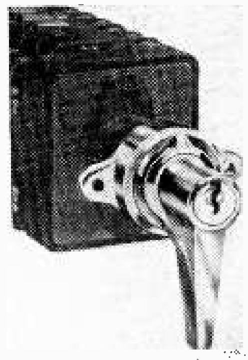


Jackson Bros. new differential and butterfly types miniature variable capacitors.

Both capacitors should find applications in v.h.f. and u.h.f. equipments where small size, low-loss and a low minimum-capacitance form of construction are primary requirements.

Lockable Switches

WITH the expansion of automation and similar forms of machinery control occasions may arise when it would be desirable to lock a master switch so that unauthorized persons cannot tamper with it. This is possible with the new lockable handle which can be fitted, when required, to the range of single and multi-way rotary switches made by Crater Products, Ltd., The Lye, St. Johns, Woking, Surrey.



Crater Products new lockable handle for their range of rotary switches.

As the illustration shows, these switch handles are of quite a new design and embody a Yale-type lock which can be secured and the key withdrawn in any of the several positions of a multi-way switch.

High-precision Frequency Standard

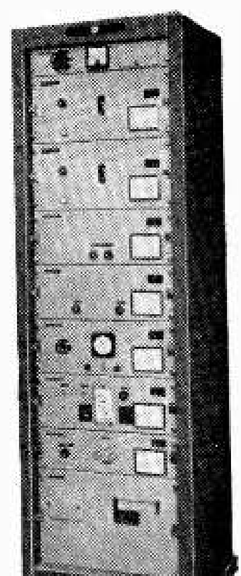
STABILIZATION of oscillators by means of quartz crystals has been the standard practice for many years past, and while frequency stabilities of the order of 1 part in 10^6 satisfies most broadcast and communications transmitter requirements, with on occasion an improvement to 1 part in 10^8, stabilities of any appreciably higher order have hitherto been difficult to achieve.

In the latest Marconi Quartz Servo Freqency Standard Equipment, Type RD101, which was exhibited at the Western Electronic Show and Convention (WESCON) at San Francisco, weekly frequency stabilities to within 2 parts in 10^{10} are achieved and the equipment should find, therefore, applications in fields of activities where extreme accuracy is essential.

Investigations by the Marconi Company have revealed that the principal obstacles to high stability in quartz crystal oscillators are mechanical vibration, valve inter-electrode capacitances and cathode impedance. At the working frequency of 5 Mc/s the two last-mentioned alone precluded attainment of the desirable minimum guaranteed stability of 1 part in 10^9.

These obstacles are claimed to have been surmounted in the Marconi Type RD101 equipment. Its principal features are:—

High-precision 5-Mc/s crystal with low drift rate and immunity from vibration. Dual stabilization of frequency by single crystal. Accurate servo systems with cathode-ray tube monitoring facilities. Uninterrupted operation during checking and maintenance. Output at least 1 volt r.m.s. (sine) into 75Ω at 10 Mc/s, 1 Mc/s and 0.1 Mc/s. Power consumption 500 VA at 200/240 V, 40 to 60 c/s a.c.



Marconi Quartz Servo Frequency Standard, Type RD101.

A PRELIMINARY SKIRMISH WITH MODERN THEORIES OF THE STRUCTURE OF MATTER

ATOMS

By "CATHODE RAY"

IN discussing such things as the construction of solids and what goes on when electric currents are flowing through them, I have hitherto uttered a warning that it would be a very simplified explanation, ignoring certain complications of modern science. These are, for example, Fermi-Dirac statistics (which are vital where transistors are concerned), the pessimistic Heisenberg uncertainty principle, the snobbish Pauli exclusion principle, the contradictory Schrödinger wave mechanics, and the notorious Einstein relativity theory, to say nothing of Planck's quantum theory. The risk of running up against these and other alarming subjects has been greatly increased by the advent of transistors. In fact, any but quite elementary or purely practical books on transistors are almost sure to bring them in.

There are two reasons why I have dodged them. One is that most of us find them difficult, because they are highly mathematical and not easily visualized. The other is that they don't help very much when taken separately, so as soon as one starts on them one is in for the lot. On the other hand, the effort is rewarded by knowledge that applies not only to transistors, or even semi-conductors in general, but to most of physical science. For instance, the book I found most helpful in studying electronics was actually written for metallurgists!*

I am not going to pretend to give a proper treatise on them, but it is a good thing to have at least a rough idea of what they are and where they fit into the general scheme. Among other things, they help to explain the conspicuous differences in the electrical resistances of metals, semi-conductors and insulators; rectification at junction and point contacts; thermionic emission; photo-electric effects; and luminescence.

Mass and Energy

There are two main themes running through all: matter (or mass) and energy. So it will be as well to begin by making sure what they mean.

Mass is related to weight, but is not the same. The weight of a thing depends on where it is. As every science-fiction reader knows, a person on the moon would be light enough to jump over a house, but if he moved to Jupiter he would be too heavy to get up out of an easy chair. But the mass of anything is always the same so long as the amount of stuff in it is unchanged. One exception is now known—the relativity effect, by which a body gains mass with speed. This is noticeable only when things move nearly as fast as light; for example, electrons in particle accelerators. The speed has to be about 15,000,000 m.p.h. to make the mass increase by 0.1%.

The textbook definition of energy is "capacity for doing work." That just passes the buck to the definition of work, which in this scientific sense doesn't correspond at all closely with what we usually understand by that word. It means motion against resistance or pressure or force. Lifting a 10-lb weight 3 feet does 30ft-lbs of work. This work imparts 30ft-lbs of potential energy to the weight, which means that by virtue of its height it is now able to do a total of 30ft-lbs of work in falling down again. By means of a pulley arrangement it could haul up another weight. Or by falling freely it could make a dent in the floor—a short distance of movement against considerable resistance. In this case the work done on the floor would be converted into a small amount of heat, which would be dissipated among the surroundings. At the moment of touching the floor the weight would have lost all its height (and therefore all its potential energy) but it would have gained velocity, which gives it another form of energy—kinetic energy. It is this energy of movement that would be converted an instant later into heat energy. Alternatively, the falling weight could be coupled to a little dynamo to convert the mechanical energy into electrical energy; and this electrical energy could do work by moving a current against a resistance, converting itself into heat energy, or by setting a current moving in an inductance, storing up the energy in a magnetic field.

There are fixed rates of exchange between all these forms of energy. It used to be believed that the total amount of energy in existence was constant, and also that the total amount of mass was constant. The release of heat energy when coal was burnt, and of mechanical energy when a bomb exploded, was attributed to "chemical energy." According to the most accurate weighing possible, the total mass of all the materials concerned was the same before and after combustion.

It is now known that this so-called chemical energy exists in the form of mass, so that when the coal burns or the bomb goes off a small part of the matter composing them is annihilated. Energy is gained at the expense of mass. The ratio of energy gained to mass lost is the square of the speed of light, so the destruction of a very small amount of mass is enough to create quite a lot of energy. One ounce is enough for 700,000,000 kilowatt-hours. In the ordinary way, nearly half a million tons of coal would have to be burnt, and one doesn't easily notice a shortage of one ounce in all the resulting ash and flue gases. It is only in transactions of the kind that go on (or off?) in H bombs that the proportion of mass destroyed is appreciable by ordinary standards. Conversely, a vast deal of energy is needed to create even a grain of matter, so there is really nothing in it for the conjurer.

Energy must be distinguished clearly from power,

* "Electrons, Atoms, Metals and Alloys", by W. Hume-Rothery (Iliffe).

which is the rate at which energy is being delivered. You pay the Electricity Board for so much energy, in kilowatt-hours (notwithstanding that they sometimes make the bill out incorrectly, for current); and it is up to you whether you use that energy in a short time to obtain a large amount of power in kilowatts, or for a long time for a low power.

Everything that goes on anywhere in the universe, on any scale from the movements of electrons, through the activities of living creatures, to the outpouring of light and heat from stars, involves redistribution of energy. The curious behaviour of things such as rectifiers and transistors depends on energy on the smallest scale, as possessed by electrons, which are component parts of atoms.

Restaurants Again

The atoms of all substances consist of a positively charged core or nucleus, surrounded by sufficient electrons to neutralize that charge. The amount of positive charge decides what substance the atom is. If it is one unit, the atom is hydrogen and has one electron (i.e., one unit of negative charge) surrounding the nucleus. If it is two units it is helium, with two electrons; if three, lithium; and so on. The highest number found in nature is 92, which is uranium. These numbers from 1 to 92, which decide what element an atom is, are known as the atomic numbers.

All the hundreds of thousands of different substances are constructed of these comparatively few elements, for atoms combine to form molecules, which usually behave quite differently from any of the ingredient elements; for example, water, each molecule of which is made up of two atoms of hydrogen and one of oxygen (Fig. 1). What is called "atomic energy" is really nuclear energy, because it results from changes in the nucleus. That is right outside our subject; the only things about the nucleus that concern us are the number of units of positive charge on it and the fact that nearly all the mass of the atom is concentrated there. The energy we are going to consider is the energy of the surrounding electrons. Although the nature of any substance—whether it is solid, liquid or gas; whether it is poisonous or nutritious; whether it is a conductor or an insulator; etc., etc.—is decided by the number of positive charges in the nucleus of each atom composing its molecule, this influence of the nucleus is exerted indirectly as a result of the number of electrons required to neutralize its charge.

It may seem strange that the nature of a substance depends on how many electrons are normally included in each atom. The strangeness increases when we learn that the actual number of electrons is often greater or less than the normal complement needed to neutralize the nuclear positive charge. For instance, a nitrogen atom has a nuclear charge of +7 units, so normally has seven electrons; but stray nitrogen atoms in a valve are liable to have an electron knocked out by the fast-moving electrons composing the anode current. Such an accident leaves one nuclear charge unneutralized, so the atom as a whole has a charge of +1 and is called a positive ion. But it retains all the usual features of nitrogen, in spite of the fact that it has only 6 electrons, which is the normal complement for carbon (Fig. 2).

The distinctive characteristics of each element and compound could not be accounted for by the normal number of electrons per atom if those electrons were stuck around the nucleus like seeds on a strawberry or buzzed around it at random like a cloud of gnats in a sunny corner of the garden, or even if they revolved around it in neat orbits at any convenient distance, like planets around the sun. It was in trying to explain how some of the most characteristic properties of substances depend on the number of electrons in each of their atoms that (in the July 1956 issue) I likened atoms to restaurants having a curious rule that the first table must be filled before anyone sits at the second, and so on.

The first table in all of them seats only two, and the next eight, so if there are ten guests both of these tables are just filled and in this sociable community there is no tendency either for one guest to go away and leave a vacancy or for another to come in and sit alone at the third table, which also seats eight. This restaurant represents an atom of neon, which is a gas that combines with no other

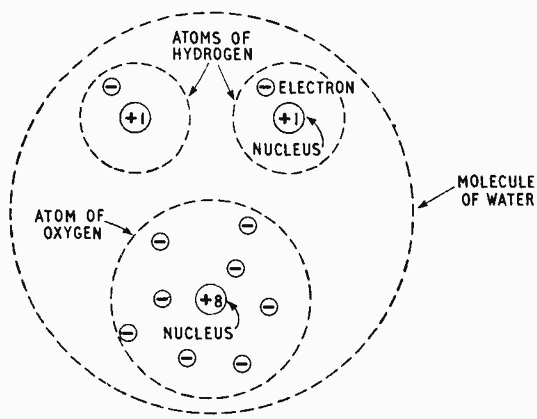


Fig. 1. Diagram showing the composition (but not the arrangement) of a molecule of water.

element at all. But the sodium atom has eleven electrons, so one electron is all by himself at the third table, feeling very much out of it. If there is a fluorine restaurant nearby, which is one with nine guests, leaving one vacancy at the second table, he quickly slips across to it, giving it a surplus of negative charge (−1 unit) and leaving behind an unneutralized positive charge (+1 unit). These charges, being opposite, attract one another so strongly that the two atoms are held together in partnership under the new name of sodium fluoride. This is one example of how compounds are formed.

I didn't think it necessary to mention that these atomic restaurants have another rule—that no more than one guest is allowed in any seat at the same time—because in any well-conducted restaurant that goes without saying. But at first sight there is no more reason why the electrons in an atom should observe a one-at-a-time rule than a rule that the "seats" must be filled in a particular order. Yet this one-at-a-time or no-petting rule is dignified in physics by the name of the Pauli Exclusion Principle. Of course, the electrons don't obey it just because a chap called Pauli said so; he did no more than call attention to a state of affairs that presumably has existed all the time. It was not until later that someone thought up a plausible explanation for the orderly behaviour of atoms.

Strange Behaviour

But you may justly be complaining that you might be able to take a more intelligent interest in the subject if you knew what the atomic " seats " are and what distinguishes one from another. This is why it was necessary to make sure about energy, because the seats are energy levels. In our earlier example of energy we considered a 10-lb weight 3 feet above the ground, and having therefore 30ft-lbs of potential energy. A similar weight—or the same one—2 feet above ground would of course have 20ft-lbs of potential energy, and so on. Just as weights are attracted to the earth, electrons are attracted to the oppositely charged and relatively heavy nucleus, and the nearer they are the less potential energy they have. A weight can be kept at any desired

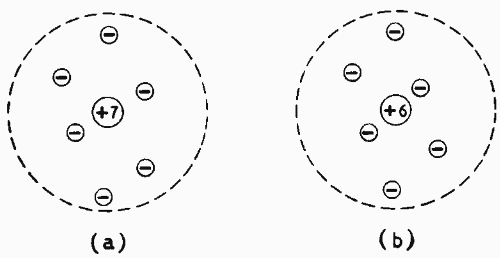


Fig. 2. Although the nature of any substance is due to the activities of its electrons rather than its nucleus, it is the normal number of electrons that decides, and that in turn is decided by the charge on the nucleus. Both these atoms have the same number of electrons, but (a) is nitrogen and (b) is carbon. (a) has been positively ionized by removing one electron.

potential energy by putting it on a shelf at the appropriate height above ground, but how can an electron be kept at a constant energy level?

We have had recent examples of how bodies can be kept a few hundred miles above the earth without any visible means of support. They are made to revolve around it at high speed, so that the gravitational pull is exactly neutralized by centrifugal force. So it is not surprising that a popular theory was that the electrons revolve around the nucleus like satellites. But this theory failed to explain why all the electrons revolved at the correct speed to maintain a stable atom, instead of just falling all the way to the nucleus once they came within its attraction. Still less did it explain the fact that such electron orbits (if orbits they were) occurred only at certain fixed distances from the nucleus. This is equivalent to a restaurant rule that guests must occupy seats at certain places, not just anywhere they fancy. According to the ordinary laws of mechanics, the kinetic energy of orbital revolution is only half of what the electrons would attain from loss of potential energy by directly falling, so the total energy of an electron is less when it is in a close orbit than when it is in a distant one; but why should it be restricted to certain fixed total energies?

The theory now in vogue is so contrary to ordinary ideas gained from what we can see around us that it is very difficult to grasp. Until comparatively recently it was assumed that electrons were solid particles of matter, similar to grains of dust but much smaller. This seemed reasonable, because they could be weighed and their individual tracks followed in " cloud chambers " in much the same way as aircraft too high to be seen can be followed by their cloud trails. Their movements through vacuum tubes seemed to conform to the laws of mechanics. Admittedly they were peculiar in having a certain fixed negative electric charge, but that was easily brought into the calculations. One could visualize them quite clearly.

Radiation—light, radio, X-rays, etc.—could also be clearly visualized as something of an entirely different kind: a form of energy, propagated as waves, and of course free from any " graininess."

In many respects these two contrasting concepts worked well in practice. To this day most of the books at elementary and engineering levels are based on them. Where they broke down most conspicuously was in the relationships between them. It was known that electrons could give up some of their energy, which emerged as radiation. And also that radiation could be absorbed by electrons, which were thereby raised to a higher level of energy. In fact, in some cases electrons were parted entirely from their atoms. A good example of this is a photoelectric cell, which is like a diode valve in which a specially prepared metal plate takes the place of the heated cathode. When light falls on the plate, electrons are emitted and can be drawn off by making the anode positive. In broad principle all this seems very reasonable. But the details are not at all as one would expect.

One would expect that the stronger the light the more violently the electrons would be ejected, and if it was very weak indeed there would be none at all. The argument (if any were needed) would be that the more intense the light, the greater would be its energy, so the more energy would be imparted to the electrons, and therefore the greater would be their kinetic energy and consequently their speed. What actually happens, however, is that the brightness of the light has no influence at all on the speed at which the electrons are emitted, but only on the number emitted in a given time. What does affect the energy with which the electrons emerge is the *colour* of the light. We know that colour is an indication of the frequency of the light waves. After allowing for a certain minimum excitation to get an electron out of the atom at all, its emergent energy is found to be proportional to the frequency of the light or other radiation. I mentioned that the cathode in a photo cell is specially prepared; this is because the electrons of most metals are too firmly held to be removed at all by radiation in the visible frequency band (i.e., light)—still less radio frequencies. X-rays have thousands of times the frequency of light, so are most potent in stripping atoms of their electrons, which emerge at high speed.

If sea waves beat against a wall made of heavy stone blocks, nothing noticeable happens to them until the waves reach a certain degree of violence; beyond that, general distintegration sets in. But if they followed the electronic example the feeblest ripples (provided their wavelengths were short enough) would pull out an occasional block here and there from the moment they started to lap against them!

The doctrine that was evolved to account for these and other apparently absurd results is known as Planck's quantum theory. The heart of it can be expressed with welcome simplicity in the celebrated equation

$$E = hf$$

The meaning of this is that energy does not flow in a continuous stream, but in "packets" (called quanta) each equal to a fixed amount h multiplied by the frequency of the energy. This h appears, like the speed of light, to be a fundamental property of the universe. But unlike the speed of light it is very small, being 6.6×10^{-34} joules per c/s. (A joule is the amount of energy equal to one watt for one second.)

Though this equation is as simple in form as Ohm's law, it has some revolutionary implications. If energy can only be delivered in packets, not "loose," then the idea of radiation streaming forth as continuous waves must be wrong. The higher the frequency (shorter the wavelength) the larger the packets. The greater the intensity of radiation at a given frequency, the more packets per second of the same size.

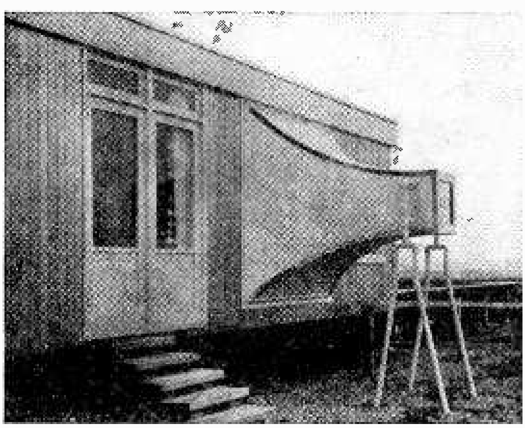
This apparently fantastic theory does at least fit in with facts that could not be accounted for by "common sense." There is the puzzling behaviour of the photo-cell, for example. And it agrees with what is known about the radiation from the electrons around atoms, which occurs at certain frequencies characteristic of the kind of atom, presumably dictated by the size of the energy jump from one fixed orbit to another closer to the nucleus. These and other agreements do not, of course, prove the theory true. And the theory certainly raises some difficulties.

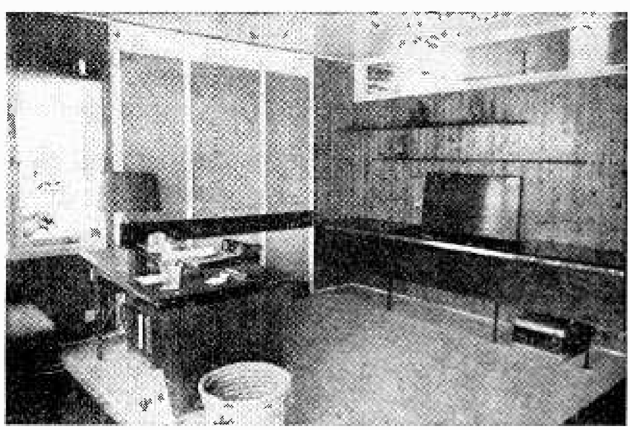
For one thing, it seems completely self-contradictory. If energy is radiated in isolated packets, like the flow of anode current in a valve, then it cannot be continuous waves, and if it is not continuous waves what is f the frequency of?

In this argument it is taken for granted that an unmodulated anode current, since it consists of separate electrons, cannot be waves. Experiments have shown, however, that sometimes a stream of electrons does behave more like a beam of waves than a stream of particles.

Well, of course, this sort of thing makes it very difficult for ordinary people to pursue a logical line of reasoning at all. We feel like Alice in Wonderland, and may be tempted to give up. But the mathematical geniuses carry on regardless and find a theory that fits the apparently contradictory facts. After all, what reason have we for assuming that the ultimate particles of which all matter is composed behave like visible particles on a small scale, or that waves of light are really like waves that we can see, only smaller? If a giant from Jupiter had such coarse sight that he could see nothing smaller than houses, we would think him very stupid if he assumed that each one was built of tiny houses.

When the facts are examined there seems to be no escape from the conclusion that instead of matter being in particles and radiated energy being in waves, both are alike in being both waves and particles. The reason why the wavelike aspect of matter escapes ordinary observation is that it is negligible except on the electron scale of magnitude. And the reason why we radio people never dream of regarding our signals crossing space as particles is that that aspect is hardly noticeable unless the frequency is much higher even than our microwaves. It is rather like Einstein's relativity, which, although it completely revolutionized ideas about the fundamental quantities—space, mass and time—yet differed from the old ideas by amounts that are negligible for nearly all practical purposes. However, transistor development is only one of many quite practical affairs that necessitate the new ideas about electrons and energy. Reconciling these two apparently incompatible aspects of them is the stickiest patch, which will come up for consideration next month.





"HI FI" BUNGALOW.—Warren House, Beaulieu, owned by Lord Montagu of Beaulieu, has been designed to incorporate an exponential loudspeaker horn with a flare diameter of 72in and length of 82in. The loudspeaker is made of fibrous plaster and is enclosed by a wooden casing packed with fibreglass. The main drive unit is a Goodmans Audiom 8, supplemented by a Wharfedale Super 8 for middle frequencies and two Super 3 units for the "highs." These are fed through a three-way crossover network from a "Quad" 12-watt amplifier and f.m. tuner, or, alternatively, from a Chapman S5 a.m. tuner. Record reproduction is via Garrard, Goldring and Danish Ortofon turntables and pickups.

New Frequency-Shift Telegraphy System

IMPROVED RECEPTION UNDER CONDITIONS OF FREQUENCY SELECTIVE FADING

IT is the usual practice for long-distance point-to-point radio communication to use the frequency-shift system of telegraphy and extract the signals at the receiving end by a discriminator as used in a conventional f.m. receiver.

In common with all systems of radio communication it is liable to interference from one cause or another, a common one being frequency selective fading due to multi-path propagation. The effect is that fading occurs on either the mark or the space frequencies independently and the customary method of combating this trouble is to use spaced, diversity aerials.

A little thought will show that with the frequency-shift telegraphy system (f.s.t.) the complete message is actually conveyed by the mark and space frequencies independently, since the absence of a mark signal on the mark frequency is a strong indication of a space signal, and *vice versa* on the space frequency. Thus there is the potentiality of frequency diversity in a f.s.t. system with only a single aerial, but it is not realizable by ordinary receiving techniques.

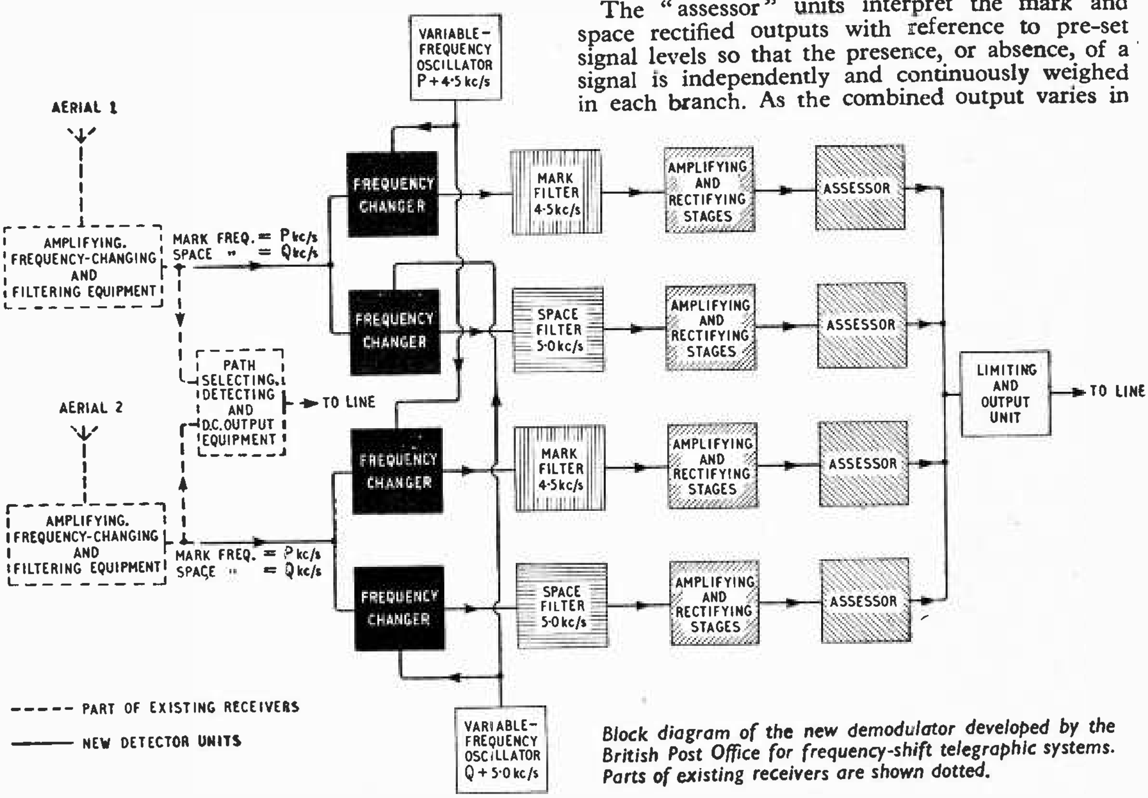
A system of f.s.t. reception which does take advantage of this form of frequency diversity has been developed by the British Post Office and is described in paper No. 2151R published in the March, 1957, Part B, *Proc. I.E.E.*

A completely new receiver is not necessary for this method of reception as it is only the detector part of the set that is affected, and a unit to replace the demodulator and its ancillary circuitry is all that is needed. The early stages of any high-grade communication receiver are suitable for feeding the new demodulator unit and the equipment is intended to be used after the final i.f. amplifiers of existing f.s.t. receivers, such as those installed in the Post Office radio stations. The block schematic diagram shows the new demodulation unit and as spaced diversity aerials are customarily employed at these stations the new demodulator is made to conform with this requirement, although it is applicable to a single-aerial system, in which case about half the equipment would be redundant.

The output mark and space frequencies of 4.5 kc/s and 5 kc/s respectively are obtained by mixing the i.f. outputs of the main receivers with the outputs of two variable-frequency oscillators.

The process of amplifying and rectifying are the same in both mark and space branches, except that the output of the mark branch is positive and that of the space branch is negative, for the "signal on" condition in both cases.

The "assessor" units interpret the mark and space rectified outputs with reference to pre-set signal levels so that the presence, or absence, of a signal is independently and continuously weighed in each branch. As the combined output varies in



Block diagram of the new demodulator developed by the British Post Office for frequency-shift telegraphic systems. Parts of existing receivers are shown dotted.

magnitude, as well as in polarity, it is further amplified and limited before passing to the land line. The circuits concerned with this operation deliver a final output of ±30 volts d.c.

The frequency stability requirements of the new method of reception are considerably more stringent that those required by international regulations for long-distance telegraphic services. On the h.f. bands, for example, these regulations permit a frequency tolerance of 30 parts in 10^6, but with the new system of reception, and with transmitters and receivers working on 15 metres, the permissible tolerance is only 25 c/s, or 1 part in 10^6. This assumes telegraphic speeds of about 100 bauds. However, such close mutual agreement is readily attainable with modern communications equipment.

Transistor Amplified A.G.C.

Economical Circuit for Use in Small Portables

BY W. WOODS-HILL

THE miniaturization of portable receivers brings in its wake some problems which are not generally encountered in full-size models. One of the more subtle of these is the very large and sudden changes in signal level encountered when a "vest pocket size" set is carried about in the hand or pocket.

The problem is rendered more difficult if transistors of low cut-off frequency are used as these do not lend themselves very well to simple a.g.c. control such as can be obtained from the d.c. voltage available at the diode detector. This lack of control springs from the fact that the source impedance of the a.g.c. voltage (diode detector) is the same or even higher than the impedance of the transistor control element, so that only half or less of the d.c. swing is available for control.

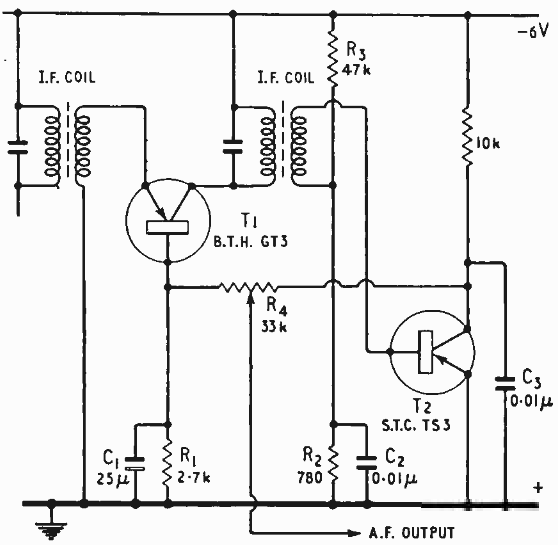
If space were not so restricted, and if cost allowed, an elaborate d.c. amplifier terminated by a suitable low impedance circuit (grounded collector) could be evolved. But even d.c. amplifiers have their drawbacks in this case, because as well as amplifying the changing voltage, they also move its level towards that of the negative h.t. line, whereas the control voltage for the i.f. stage is required at a small negative (−0.16V) bias voltage close to the earth line. To achieve this bias a voltage dividing network must be inserted between the collector of the d.c. amplifier and earth, which besides "dividing down" the voltage to the required level, unfortunately also divides down the controlling voltage swing available. This therefore tends to defeat the main objective, which is to obtain a large voltage swing for a small change of signal amplitude.

If the bulk of a separate battery could be tolerated, then the undivided voltage available at the collector could be directly connected to the base of the i.f. transistors. However, this circuit would probably rapidly go out of adjustment due to irregular fall of both battery voltages with age.

A Practical Circuit. The ideal amplified a.g.c. system would work without any extra supply batteries, be independent of normal battery voltage fluctuations with age, and use no more components or transistors than a more usual system.

The diagram shows a circuit which approaches this ideal. It has been successfully used by the author and gives a good a.g.c. action.

The transistor T2 combines the function of second detector, audio amplifier and a.g.c. voltage amplifier.



Practical application of a.g.c. principle described, showing detector/a.g.c. and last i.f. transistors.

The ability of this transistor to perform all these functions hinges on the fact that junction transistors exhibit a "pentode like" characteristic whereby the current is independent of collector volts over a wide range of voltages, right down to about −0.3V. This means both that the mean operating potential of the collector can be brought down close to the earth line (say to −3.5V), so that little voltage dividing is necessary to bring it down to the −0.16V required as bias for the i.f. stage, and also that a high collector load can be used, thus giving correspondingly high d.c. amplification. Despite this low collector voltage it still operates reasonably linearly, and does not add any appreciable extra distortion to the audio signal. Moreover, its detection efficiency is little impaired by these operating conditions.

If a volume control for the audio signal appearing at the collector of T2 is needed, then it is quite in order to use the resistance of the fixed portion of the potentiometer as one leg of the a.g.c. voltage divider connecting the collector of T2 to the base of the last i.f. transistor T1, as in the diagram, provided that the bottom of this potentiometer is decoupled to earth at audio frequencies by the condenser C1.

Circuit Operation. Under low-signal conditions the potential at the collector of T2 is 3.5V and that at the base of T1 0.16V. As the r.f. signal applied to the base of T2 increases in amplitude the average current in T2 will increase, because, during the negative r.f. half cycle signal swings, the forward bias set by R_3 and R_2 is increased so that the d.c. level at the collector falls towards earth. The extent of this fall naturally depends on the increase of signal at the base of T2, but with a dummy load on T2 instead of the i.f. stages (no a.g.c. in action), has been noted to fall as far as from 3.5V to 0.6V. This would normally have represented a fall in bias from 0.16V to about 0.03V had the circuit been connected to the i.f. transistor bases. However, with a.g.c. in action this is most unlikely to occur because the i.f. sensitivity falls very rapidly below 0.09V bias, so that a signal which was potentially capable of producing such a fall would have been sufficiently reduced by the i.f. stages becoming desensitized. The aim is to maintain good audio quality even under strong signal conditions by ensuring that the voltage at the collector of T2 does not fall below the knee of the collector-current/collector-voltage curve at 0.3V.

Condenser C_3 is, of course, a filter for r.f. decoupling.

Circuit Design. It is difficult to be specific about what values to use in a circuit of this type, because the characteristics of junction transistors vary greatly between different types and also to some extent between individual samples of the same type. However, if the principles are understood it should be reasonably easy to evolve a suitable circuit for whatever type of transistor is proposed, and then make one of the components, e.g. R_3, variable to take up any differences between samples of the same type.

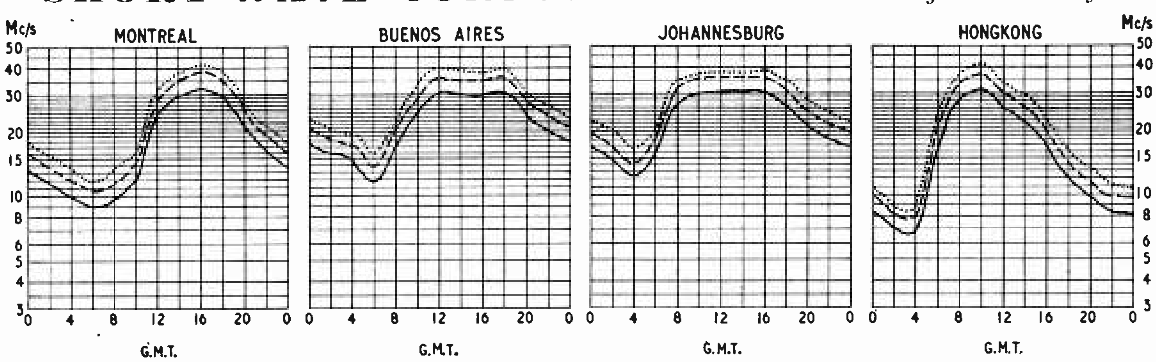
The first criterion is that the voltage at the collector of T2 must not be allowed to fall below the knee given in the manufacturers' collector-voltage/collector-current curves. To achieve this, arrange the forward bias on the base of T2 to be between $\frac{1}{2}$ and $\frac{1}{4}$ of what the manufacturers recommend for class A operation. A fixed bias is required because the collector-current/emitter-current curve is not linear close to cut-off. Choose a collector load which under these conditions gives a collector voltage which is about ten times the knee of the bend. Make the value of resistance R_1 connecting the base of the T1 to its emitter as large as possible, yet not so large that any appreciable gain is obtained with no negative bias connected. A resistance R_4 should be connected between T2 collector and T1 base of such a value that the i.f. transistors receive the recommended bias.

Should the value of this resistance cause the voltage on the collector of T2 to fall below 3.5V under no-signal conditions, then the collector load should be reduced and R_3 increased, until the collector potential reaches 3.5V and the i.f. transistors are receiving their correct bias.

Effect of Battery Supply Variations. Assuming the battery supply voltage falls with use then, because the bleeders R_3 and R_2 are specifying the bias applied to the base of T2, this bias will also fall, causing a reduction of the current through T2. This causes the voltage at the collector (which is also the source of the a.g.c. voltage to the i.f. transistors) to increase. On the other hand, by stipulation, the supply volts to the collector of T2 have fallen, so that this increase will not be as marked as might at first be thought.

The overall effect of decreasing battery voltage on the entire set is a general falling off in liveliness, but this is partly compensated by increasing i.f. stage sensitivity due to the increasing bias discussed above. In fact, R_3 can be so adjusted that the set will become more lively with use (as the battery voltage falls) though, as might be expected, the quality begins to suffer due to improper operation of the audio stages.

SHORT-WAVE CONDITIONS *Prediction for February*



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 February.

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

News from the Industry

G.B.C. Electronic Industries, Ltd., has been formed by H. V. Bolsom and L. M. Bolsom who have resigned their directorships of the Champion Electric group of companies which was recently taken over by Thorn Electrical Industries. The new company, which has offices at 119, Edgware Road, London, W.2 (Tel.: Ambassador 2872), has been formed to import and distribute tape recorders and electronic equipment. The first two tape recorders to be handled are the miniature battery-operated transistorized Phonotrix made in Germany and the Italian mains-operated Phonetic.

Bonochord has been merged with W.S. Electronics, both firms being members of the K.G. (Holdings) group of companies. The trade name Bonochord will continue to be used for hearing aids and auditory equipment. Bonochord's offices and showroom at 48, Welbeck Street, London, W.1, will continue, but production is now centred at the W.S. Electronics works at 44, Brunel Road, London, W.3. Colonel A. E. Tyler is general manager of W.S. Electronics, Ltd., B. J. Brown is works manager, and R. A. Cail technical manager.

Multimusic, Ltd., has been formed as a wholly owned subsidiary of Multicore Solders, Ltd., with a view to marketing products in the field of magnetic tape recording and reproduction. The company's formation reflects the interest of Multicore's chairman and managing director, Richard Arbib, in sound reproduction.

Gramophone records of flexible, transparent, cellulose acetate, only 0.003-inch thick, for use as advertising "gimmicks," are now available in this country. Rainbow records, as they are called can be attached to the walls of a cereal carton, for instance. Playing time at 78 r.p.m. averages from 70 secs on a five-inch disc to 140 secs on a seven-inch record. L.P. records can also be made. The equipment, installed by Everest Plastics, Ltd., of 45-46, Morley House, 320, Regent Street, London, W.1, for the cartons division of E. S. & A. Robinson, Ltd., at Fishponds, Bristol, can produce 40,000 impressions per day.

H. W. Forrest, Ltd.—The note in last month's "News from the Industry" on this company's introduction of transformers for a.f. transistors inadvertently came under the heading "New Addresses." The company, established in 1922, has been at its present address, 349, Haslucks Green Road, Shirley, Solihull, Warwickshire, for many years.

E-V, Ltd., formerly Sapphire Bearings, Ltd., the sapphire stylus and ceramic cartridge manufacturers, has a reconstituted board of directors. John Dalgleish, chairman and managing director of Camp Bird, Ltd., the parent company, is chairman, P. J. N. Collaro, who recently resigned from Collaro, Ltd., is managing director, and Dr. F. E. Templeman is technical director. A. P. Riding is also on the board. D. Robinson, previously managing director of E-V, is now managing director of Ambassador. A new company, Electronic Reproducers, Ltd., which will be primarily concerned with the manufacture of crystal cartridges, has been formed by the group. It will operate under the chairmanship of P. J. N. Collaro, with Dr. F. E. Templeman as technical director.

Mullard's 4MeV linear accelerator is being installed by Philips Electrical at the research station of British Petroleum, Ltd., at Sunbury-on-Thames, Middlesex. In this connection it has many applications, including the production of electron beams for initiating polymerization and the production of new materials by molecular re-arrangement or graft techniques.

Millionth television receiver off the Ekco production line at Southend-on-Sea (a 17-inch table model with v.h.f. sound) was presented to a local children's home. E. K. Cole started manufacturing television receivers in 1936, but since production reopened in 1946 over 980,000 receivers have been made.

Automatic Telephone & Electric Co., who have supplied considerable quantities of telegraph equipment to the U.S. airforce in this country, has received further orders valued at £76,000 for telegraph distortion measuring sets and electronic regenerative repeaters. TDMS equipment was shown by A. T. & E. at the Washington exhibition of the Armed Forces Communications & Electronics Association last year.

Thirty television cameras and associated equipment have been ordered by the B.B.C. for the new television centre at White City, where the first three studios are planned to be brought into service in 1961. The cameras will use 4½-in tubes of the image-orthicon type and the order is shared equally between E.M.I. and Marconi's.

Aerialite, Ltd., have produced their 40 millionth aerial. To mark the occasion a voucher of £100 has been packed with the aerial, and ten other aerials carry a £10 voucher.

Printed Circuits, Ltd., of Stirling Corner, Barnet By-Pass, Borehamwood, Herts, recently announced that they are prepared to undertake the quantity production of almost any form of printed circuit at a fixed cost of 1d per square inch. This figure includes raw materials and processing but excludes the cost of special tools.

OVERSEAS TRADE

Multi-channel radio telecommunications equipment to link the towns of Luanda, Malange and Marechal Carmona in Angola (Portuguese West Africa) is to be supplied by Marconi's and A. T. & E. The order was obtained from the Angolan postal and telegraph authorities through the companies' associates, Automática Eléctrica Portuguesa (S.A.R.L.). The total distance covered will be about 400 miles. Marconi's will supply the terminal transmitters and 16 repeaters and A. T. & E. the carrier telephone equipment.

Radio telephone equipment valued at over $100,000 has been ordered from Pye by the Veterans' Taxi Cab Company of Montreal.

Masts for the most northerly coast radio station in the world—at Isfjord, West Spitzbergen, were supplied by B. I. Callender's Construction Co. Four 120-ft. masts support the station's aerial.

Brussels International Exhibition.—A display of consumer goods is being arranged by the Council of Industrial Design for the British industries pavilion at the Brussels Exhibition (April 17th to October 19th). Among the sound and television receiver manufacturers who have agreed to participate in the display are Bush, Cossor, Ekco, E.A.R., Philco, Portogram and Trix.

Belgium.—One of the twenty sections of the Liége International Fair, which is being held from May 10th to 26th, will cover electrical and electronic equipment. British manufacturers are being offered specially reduced rates for space. Further information is available from the U.K. representative of the Fair, R. C. Liebman, 178, Fleet Street, London, E.C.4.

France.—Lille International Trade Fair (April 19th to May 4th) will include a section for domestic sound and television receivers. Particulars are obtainable from the Commissariat General, Grand Palais, Foire de Lille, Lille (Nord).

FEBRUARY MEETINGS

LONDON

5th. Brit.I.R.E.—"Radio investigations during the I.G.Y." by Dr. W. J. G. Beynon at 6.30 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

6th. I.E.E.—49th Kelvin Lecture on "High polymers" by Dr. H. W. Melville at 5.30 at Savoy Place, W.C.2.

7th. Television Society.—"The effects of noise in television transmission" by T. Kilvington (Post Office Eng. Dept.) at 7.0 at the Cinematograph Exhibitors' Association, 164 Shaftesbury Avenue, W.C.2.

12th. Radar Association.—"The early days of radar" by Sir Robert Watson-Watt at 7.30 at the Anatomy Theatre, University College, Gower Street, W.C.1.

14th. R.S.G.B.—"The television interference problem" by G. A. Bird (G.P.O.) at 6.30 at the I.E.E., Savoy Place, W.C.2.

18th. I.E.E.—"Magnetic tape for data recording" by Dr. C. D. Mee at 5.30 at Savoy Place, W.C.2.

19th. I.E.E.—"The relation between picture size, viewing distance and picture quality with special reference to colour television and to spot-wobble techniques" by L. C. Jesty at 5.30 at Savoy Place, W.C.2.

20th. Television Society.—"Test equipment for colour television receivers" by F. H. Cohen and D. C. Kidd (Murphy) at 7.0 at the Cinematograph Exhibitors' Association, 164 Shaftesbury Avenue, W.C.2.

21st. B.S.R.A.—"Reducing distortion in f.m. reception" by Dr. G. J. Phillips at 7.15 at the Royal Society of Arts, John Adam Street, Adelphi, W.C.2.

24th. I.E.E.—"Stereophonic recording on gramophone discs" by H. A. M. Clark at 5.30 at Savoy Place, W.C.2.

26th. Brit.I.R.E.—"Dectra: a long-range navigational aid" by C. Powell at 6.30 at London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

26th. Women's Engineering Society.—"Three case studies in automation" by G. Denton at 6.45 at Central Electricity Authority Headquarters, Winsley Street, W.1.

ARBORFIELD

11th. I.E.E. Graduate and Student Section.—"The tracking of the Russian earth satellite" by D. L. Cooper-Jones at 7.0 in the Assembly Hall, 3 (Tels.) Training Bn., R.E.M.E.

BIRKENHEAD

19th. Brit.I.R.E.—"Closed-circuit television" by J. G. M. Downes at 7.0 at the Technical College.

BIRMINGHAM

3rd. I.E.E.—Discussion on "The place of liberal studies in a technical institution" opened by E. H. Horrocks at 6.0 at the James Watt Memorial Institute, Great Charles Street.

BRISTOL

11th. Television Society.—"I.G.Y." by A. F. Collins at 7.30 at the Hawthorns Hotel, Woodland Road.

CAMBRIDGE

4th. I.E.E.—"Problems of sound and television broadcasting coverage" by G. Millington at 8.0 at the Cavendish Laboratory, Free School Lane.

25th. I.E.E.—"The eye as a television camera" by Dr. F. W. Campbell at 8.0 at the Physiological Laboratory.

CHELMSFORD

4th. I.E.E. Graduate and Student Section.—"Transistor amplifier circuits" by W. A. Thorpe at 7.0 at the Public Library.

CHELTENHAM

28th. Brit.I.R.E. — "Information theory" by P. H. Blundell at 7.0 in the North Gloucestershire Technical College.

EDINBURGH

21st. Brit.I.R.E.—"Frequency response instrumentation for the analysis, design and construction of servo-mechanisms" by G. R. Swainston at 7.0 at the Department of Natural Philosophy, the University.

GLASGOW

20th. Brit.I.R.E.—"Frequency response instrumentation for the analysis, design and construction of servo-mechanisms" by G. R. Swainston at 7.0 at the Institution of Engineers and Shipbuilders, 39 Elmbank Crescent.

MANCHESTER

6th. Brit.I.R.E.—"Electronic musical instruments" by Alan Douglas at 6.30 at the Reynolds Hall, College of Technology, Sackville Street.

11th. I.E.E.—"Electric control of stage and television lighting" by F. P. Bentham at 6.15 at the Engineers' Club, 17 Albert Square.

NEWCASTLE

12th. Brit.I.R.E.—Students' night at 6.0 at the Institution of Mining and Mechanical Engineers, Neville Hall, Westgate Road.

RUGBY

25th. I.E.E.—"The importance of research in hearing and seeing to the future of telecommunication engineering" by Dr. E. C. Cherry at 6.30 at the Technical College.

TREFOREST

26th. Brit.I.R.E.—"Industrial television" by R. Swinden and J. E. H. Brace at 6.30 at Glamorgan Technical College.

WOLVERHAMPTON

12th. Brit.I.R.E.—"Industrial applications of radio isotopes" by R. F. Armitage at 7.15 at the Wolverhampton and Staffordshire Technical College, Wulfruna Street.

LATE-JANUARY MEETING

31st. Brit.I.R.E.—"Digital computers" by R. Deighton at 7.0 in Priory Lodge Hall, Malvern (not the Winter Gardens, Malvern, as stated in the last issue).

RANDOM RADIATIONS

By "DIALLIST"

Whistling TV Sets

THE letter from D. A. Thoms in the January issue of *Wireless World* on the subject of whistle from the line output transformer interested me greatly. Though I can no longer hear this whistle unless I'm close to the receiver and make an effort to do so, I know quite a few people who find it so distressing that they cannot bear to watch television. Some manufacturers make greater efforts than others to minimize it by carefully padding the transformers; but it is a shortcoming in the TV receiver which urgently needs attention. American manufacturers and those in other countries have not the same problem as ours. In the American 525-line, 30-frame system the whistle has a frequency of 15.75 kc/s, in countries using the 625-line, 25-frame system it is 15.625 kc/s. Both of these frequencies should normally be all but inaudible to other than very young ears. As for the French 819-line, 25-frame system, its whistle with a frequency above 20 kc/s is nothing for anyone to worry about. I don't quite see how the whistle in our receivers is going to be cured so long as we continue to use a shock-excited winding in the transformer to produce the e.h.t. voltage. But there are other ways of doing this and I'm sure that the first manufacturer who brings out a whistle-free TV set and makes a strong point of this quality will find large sales for his wares.

Interference Suppression

REGULATIONS on the radiation of interference so far issued by the P.M.G. cover motor ignition systems, small electric motors and refrigerators and a committee is now investigating interference from scientific, industrial and medical equipment. But there are many other sources of interference which can cause serious annoyance to neighbours using their sound and TV receivers and, so far as I can find out, there's nothing except consideration for others and common decency to prevent anyone from using such unsuppressed equipment. Fluorescent lamps, for instance. A small percentage of these can, and do, cause horrible interference. How effective proper suppression can be one knows from visits to the Radio Show in the last few years—hundreds of these lamps, but not a trace of interference from any of them on the TV screens on the stands. Then there are various kinds of apparatus using thermostats. Most, if not all, of those sold in, say, the last three years are suppressed; but the older ones very often aren't. Electric razors come into the "motor" category. Few are in use during viewing hours, save, perhaps, by the more hirsute who need a trim up before going out for the evening or on night duty. Here again all the newer ones have adequate suppression, though the older ones haven't. Motor-operated toys aren't always properly suppressed and since they may be used at odd moments at any time of the day up to say 9 or 10 o'clock, the P.O. engineers may find it very difficult to track down offenders. One friend of mine was almost driven off his head by violent interference, always most frequent on wet days, which never occurred after 8 o'clock in the evening. The P.O. engineers were very good about it, paying visit after fruitless visit. Then they came on a wet day and found it in full swing. It didn't then take them long to discover that the source was a small boy's electric railway, which had been sent him from abroad as a present.

Best TV Screen Height

BEFORE now I've mentioned that if you want comfortable television viewing, as no doubt you do, it's most important that the screen should be at just the right height. In many consoles the screen is too low and you can't do much about it. The table model you can put on to a table of about the right height, raising the set if need be by methods which can safely be left to the ingenuity of *W.W.* readers. And there's an even better way that that. At least one firm* is now marketing a most ingenious trolley, which enables the screen to be adjusted to any height up to five feet from the floor. While the trolley is being wheeled about the set remains on the ground floor, so to speak. But when it's in position you can raise the set to any height you like without any kind of heaving. The set lives in a delicately balanced cradle and when you feel that the height is just what it should be, you stop raising and this locks automatically. To put the set to bed, you simply press a small lever and down it goes as lightly as a feather. A very tall console would be rather unsightly on such a trolley; but I can't see any reason why something similar shouldn't be worked out for sets housed in console cabinets of the more usual size.

* Rediffusion Vision Service, Ltd., of Chessington, Surrey.

South Africa Looks In

WRITING from Germiston, South Africa, a reader who is an enthusiastic DX-er tells me that he receives pictures from the Crystal Palace almost every evening between five o'clock and seven o'clock, local time. South African standard time is two hours ahead of ours, so he must be getting the afternoon programmes. His set, made by himself, is the *Wireless World* superhet, of which constructional details were published in 1949. He has made certain modifications to the r.f. section and his local oscillator is crystal-controlled. He has three headaches; the pictures are rather "snowy," though that's surely to be expected; the line timebase is difficult to keep in sync and there's interference at times from the second harmonic of Rome's 21-Mc/s sound service for South Africa. Still, I'm sure it's a wonderful show and one which both he and the designer of the set may well be proud. I was sorry not to be able to comply with his request for circuit details of the Synchroguide system, which I mentioned in these notes a while ago. It's a proprietory device and so far as I know it is supplied only to TV set manufacturers. I hope this South African reader will let me know how he gets on now the Crystal Palace e.r.p. has gone up to 200 kW.

The Wrotham Question

THERE seemed to be so much doubt about the upper limit of Wrotham's audio frequency band that I applied to the B.B.C.'s engineering information department for help in clearing things up. In their reply they state that both the transmitters at Wrotham and the lines between London and Wrotham are capable of dealing faithfully with frequencies up to 15 kc/s. Though implied, it is not definitely stated that the full 15-kc/s band is always used; but from experience of these transmissions I feel pretty sure that, as a rule at any rate, it is. There may be times when the connecting lines are not right up to the mark; but the P.O. engineers who are responsible for their maintenance are so strict about their standards that I fancy that these are few and far between.

Setback for French TV

AS one of its economy measures, the French Government recently decided that it could not provide the money needed for the expansion of the 819-line network. This must mean that quite considerable areas of the country will remain without a television service for some time to come. In his editorial in the December number of *Télévision* E. Aisberg argues strongly that this is false economy. He gives figures which go to prove the assertion of Gabriel Delaunay, director general of R.T.F., that so far as the French government is concerned television is a paying business. The transmitter at Lille is taken by Aisberg as an example to drive the point home. Reckoning the franc in round figures at 1,000 to the pound sterling, the cost of the station was £200,000. Since it was opened some four years ago 180,000 TV sets have been sold in its service area and by various taxes the State has profited to the tune of £6,000,000 from their sale. It has in addition received not far short of £200,000 in the form of licence fees.

Making it More Difficult

THOUGH I'm all in favour of using small letters in such abbreviations as v.h.f., e.h.t., and so on, I'm dead against the custom adopted by some American publications of leaving out the full-stops. In these, for example, i.f. is written if, which naturally jumps to the eye as the conjunction and in reading an article in which intermediate frequencies are referred to you (or at any rate I) have to be constantly on the alert to distinguish the ifs which are conjunctions from those which are abbreviations. To my mind the authors and publishers of technical books and articles should do all they can to make things easier and not more difficult for the reader.

UNBIASED

By FREE GRID

Chirographic Chores

WHEN I wish to write a letter to my blonde or prepare these few notes for you, one of the most difficult and wearisome tasks is, I find, the pushing of the pen or the hammering of the typewriter keys, at neither of which I am expert.*

The word calligraphy is definitely a misnomer for my handwriting and I prefer to use the more correct term chirography, although unkind people have suggested that podography would be more accurate.

To escape the chirographic chore of the pen or the tyranny of the typewriter, I have tried using a tape recorder, but it is not too satisfactory. I find I like to be able to *read* what I have "written" and not merely to *listen* to it. The day is still far distant when the human voice will be able to operate a typewriter direct, but I think I am definitely on the track of an idea which will eradicate wearisome pen pushing or typewriter tapping. Like all great ideas and inventions it is very simple.

We all know that a musician can read a musical score with the same

Free Grid reading a "score"
(Reproduced from "W.W." February 3rd, 1933)

ease with which you and I read *Wireless World*. It is perhaps less well known that anybody willing to try the experiment can learn to read English written in the Greek or Cyrillic alphabet with the same ease and speed as he can read it in the normal Roman alphabet.

A quarter of a century ago I told you how I had learned to "read" the wiggles of a gramophone recording, and I reproduce a sketch of myself doing it which was published at the time. It is true I was following the score of a musical recording, but it would be just as easy to read speech.

My proposal is, therefore, that we should drop two of the three "Rs" in our school curriculum and teach children to read the "script" of a gramophone record and to "write" by using a microphone. We should, of course, need our recordings on tape rather than disc.

It would not be possible to read magnetic tape direct without applying messy magnetic powder but what could be easier than to pass it through a simple electronic transcribing machine? The recording would be amplified in the usual way and then passed, not to a loudspeaker, but to a cathode-ray tube and made to appear as wavy lines.

I am convinced that one day my idea will be turned into glorious reality, and the myriads of typists in our offices will be retained solely for ornamental purposes, a function which many of them fulfil so ably already in addition to their other duties.

Can you see any fundamental objection to the idea? After all, Rudolf Pfenniger painted recordings on film long years ago.

* A masterly understatement.—Ed.

Pepys on Tape

IN MY opinion a well-kept diary is one of the most entertaining and, as with Mr. Pepys', instructive forms of literature. Judging by the popularity of Mrs. Dale's diary I am not the only one who finds a personal journal entertaining.

Like many other people I have kept a diary spasmodically and recently I picked up one which I kept long ago and I was soon engrossed in its pages. It dealt largely with a blonde I knew in those days and I read the faded ink of my record with mounting interest and excitement. I had just reached a critical point when, in a serial, one would come to the frustrating phrase "Another gripping instalment next week" and I turned over the page eagerly only to find it blank. I had obviously been suddenly interrupted—I mean, of course, in the writing of the diary—and had thereafter, for some unknown reason, not filled in the diary for several weeks, and so I shall always wonder what happened next as my memory does not help me.

I am glad to say, however, that this sort of thing is not likely to happen again as I have called electronics to my aid and am keeping a diary in trouble-free form. Instead of wearily pushing a pen at the end of the day I merely pick up the mike of a tape recorder. This is straight forward enough but I have taken a leaf out of Mrs. Dale's book by recording surreptiously the conversations I have with my friends.

I use a pocket recorder and a "buttonhole" mike which I have adapted in the form of a cuff link so that by suitably placing my arm in an apparently negligent pose I can put the mike in the most advantageous position.

A few weeks ago I took my apparatus with me when I paid a visit to friends whom I had not seen for many years. Mrs. Free Grid was with me and naturally her tongue and those of the other ladies present were soon busy saying things about absent friends which if repeated before witnesses would land them in an action for slander. In fact, the whole business has made me rather uneasy. If the cult of the pocket recorder becomes as popular as that of the candid camera we shall all have to guard our tongues for we shall never know when we are being "taped."

There is one ray of comfort and that is that I doubt very much whether evidence from a tape recorder would be admissible in court. Perhaps readers who are learned in the law can give me the benefit of counsels' opinion on this point.

Luxembourg on V.H.F.

IT is an astonishing thing to me how few broadcast receivers there are on the market which cater for v.h.f. only. I speak from bitter experience, as I have recently had very great difficulty in locating one. Reception of v.h.f. sound is available in some TV sets and also in many sets covering medium waves and, in some cases, the long-wave band as well.

What I object to is that I am compelled to pay for something I don't want, such as a medium- and long-wave range, in order to get something I do want. That means I am paying a higher price than I need to do. This idea seems to be copied from the coal industry's bad example of making us all buy a lot of slate in order to get a little coal.

I do hope that at the next National Radio Show, in which there is to be an audio section for the "hi-fi" enthusiasts, we shall see plenty of "v.h.f. only" sound sets. But a radio dealer tells me that this is not very likely, and the reason can be summed up in one word, "Luxembourg."

If that indeed is the reason I can only say that the sooner the B.B.C. relays Luxembourg in its v.h.f. service the sooner shall we be able to buy "v.h.f. only" sets at mass-production prices.