EDITORIAL COMMENT

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INFORMATION THEORY AND BROADCASTING

Broadcasting techniques are now pretty well established, both on the engineering and programme sides. But, all the same, it might be a worth-while New Year's resolution for broadcasters to decide upon a re-examination of these techniques in the light of information theory. That theory, it will be remembered, did not originally concern itself with the *meaning* of the message or symbols transmitted. Of recent years, however, there has been a growing tendency to widen the scope of the theory, even to the extent of trying to fit the human mind into its place as a link of calculable capacity in a chain of communication.

There is already quite a formidable and highly esoteric literature on this widened aspect of information theory. "Formidable" seems to be a singularly appropriate word in this context; any attempt directly to apply the principles enunciated to say, the improvement of broadcast programme techniques, leads us into deep and turgid waters. But even an unsuccessful attempt may bring up useful ideas.

For instance, the rate at which the human mind can assimilate information is always strictly limited, though it varies with the individual. This truism is brought out in an easily digestible form (though it must be admitted with no reference to information theory) in Professor Kapp's book* on technical writing. All the author's principles are applicable to some extent to the presentation of any kind of factual information (as opposed to imaginative writing or speaking) whether by the written or spoken word. The information in many broadcast talks seems to us to be presented at a rate that is far too high for the medium of communication. Some of them, indeed, can hardly be assimilated at a first reading when they are reprinted in *The Listener*, except perhaps by specialists.

What appears to be another fundamental misuse of broadcasting, considered purely as a means of communication, is the employment of it for disseminating information of purely local interest. Surely that is a function that can be much better carried out by local newspapers. The inhabitant of, say, a small town is almost certain to waste a vast amount of time in waiting for news of happenings in his own little community—if it ever comes. And, taking the South-Eastern broadcasting region of England, what common denominator of local interest can be found to link a London suburb, a New Town, a cathedral city and a secluded village?

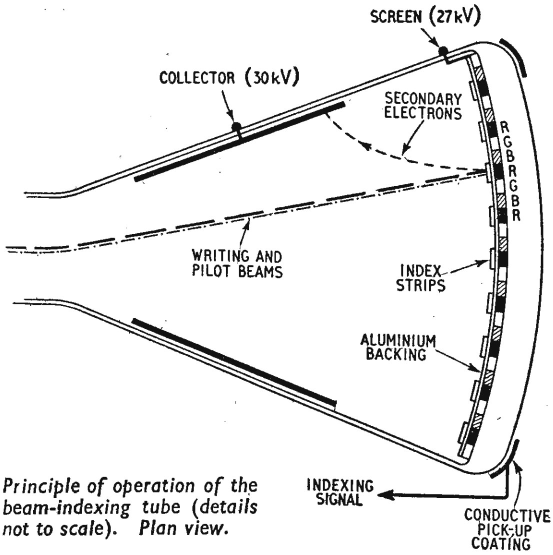
This technically indefensible use of the radio medium for parish pump broadcasting, though representing an error of principle, is not highly significant in volume. On the wider issue, much of the philosophy behind the concept of regional programmes, to which the B.B.C. has long been devoted, seems to be based on an almost equally serious misconception of the proper use of the radio medium. For a small country like England, surely radio is essentially adapted to distributing material of nation-wide interest. For example, a high proportion of listeners served on medium waves by the West Region must feel a much closer affinity with London than with the robust and rural West Country.

* "The Presentation of Technical Writing" by R. O. Kapp. Constable.

Single-beam Colour Tube

ONE of the main brakes on the development of colour television at present is the absence of a really cheap and simple colour display device that will make possible a low-cost receiver. It is doubtful whether the well-known three-gun shadow-mask tube is the best basis for this. Not only do three guns add to the expense of manufacture but they bring with them all the problems of registration (which are by no means solved in existing designs) and necessitate two extra wideband video output stages capable of providing about 100 volts swing and a stable black level.

Fundamentally, what is required is a single electron gun controlled by a brightness signal, and a screen consisting of a mosaic of differently coloured phosphor dots or strips, with some mechanism which ensures that the spot excites only appropriately coloured dots or strips depending on the colour signal.



Principle of operation of the beam-indexing tube (details not to scale). Plan view.

The Chromatron, or Lawrence tube, is one device that goes some way towards the ideal (see July, 1953, issue, p. 329). Another, more recent, design is a single-beam tube developed by Philco in America which has hitherto been known by the code name "Apple." In this, as shown by the figure, the screen comprises a pattern of vertical phosphor strips arranged in the cyclic order R G B R G B, etc. There is no internal structure comparable with the shadow-mask in the three-gun tube or the colour-controlling grid in the Chromatron, but on the inside face of the aluminium film backing the phosphor strips there are strips of magnesium oxide which register with a particular one of the phosphor strips.

The principle of operation here is that the incoming colour information is switched to modulate the tube according to the position of the beam. In other words, when the beam is passing across the red phosphor strip the red signal is switched to the electron gun, when the beam is on the green strip the green signal is switched on, and similarly with the blue strip.

In order to do this, some means must be incorporated for continuously giving information on the position of the beam across the screen. This is achieved by means of a "pilot" beam (travelling parallel with the normal "writing" beam) in conjunction with the magnesium oxide strips on the screen. Magnesium oxide has a higher secondary emission coefficient than the screen's aluminium backing, so that when the pilot beam crosses the strips it produces a greater secondary emission current than from the aluminium between, and a regular pulsation is obtained. The secondary electrons are picked up by the conical collector electrode, which is at 30kV relative to the screen's 27kV.

The pulsation of secondary emission current generates a signal at the screen, which is taken off capacitively by an external conductive coating. This waveform is known as an "indexing" signal and is combined with the colour signal to gate the writing beam at appropriate moments to produce the desired colours.

In the absence of the colour signal the "Apple" tube produces a good black-and-white picture, simply because the writing beam energizes all the phosphors equally as it passes over them in rapid succession. No critical adjustments are required as in the three-gun tube, where the three separate beams must be correctly aligned and matched to give satisfactory colour—and monochrome—reproduction.

Tubes of this kind are known generally as "beam indexing" tubes. The main advantage claimed for the Philco version is that the task of maintaining tight tolerances is relegated to the manufacturing equipment rather than to the tube itself, where it would have to be faced every time a tube is made. Another important point is that no high-voltage power is wasted through interception or deflection of the beam by an electrode structure near the screen. Technicians in this country have, however, complained of a pattern of vertical dark lines on the picture which results from the screen construction. Full details of the tube have been published in the September, 1956, issue of *Proc. I.R.E.*

Tubeless Colour Television?

LOOKING forward beyond the single-beam tube and the flat tube (described last month), many people believe that the ultimate colour display will be a "picture-on-the-wall" device utilizing some solid-state phenomenon such as electro-luminescence. This method of producing light from phosphors by directly applied potentials* is now being actively investigated, mainly for lighting purposes and image intensification, but there is no doubt that the research workers have their eyes wide open for possible applications in television.

The problem of constructing such an electro-luminescent colour display was raised by a speaker at a recent Brit. I.R.E. lecture on the light amplifier given by Dr. T. B. Tomlinson of G.E.C. It has been discovered that the light emitted from the phosphor can be made to change colour with different frequencies of a.c. excitation, and the speaker suggested that this effect might be exploited in some way. In reply Dr. Tomlinson said that the change with frequency could only be accomplished between green and blue, and in practice the method was only suitable for producing an overall colour change in complete sheets of phosphor.

He felt that a more likely solution would be a mosaic type of screen made up of phosphor dots of different electro-luminescent materials, with some arrangement for activating the dots separately in synchronism with the scanning process. A method which has already been suggested involves a matrix consisting of horizontal wires on one side of the screen and vertical wires on the other. Each phosphor dot is placed at the intersection point of an x wire and a y wire and, in theory, can be activated separately by applying the appropriate voltage to these electrodes. Apart from the elaborate and high-speed switching system required for scanning the matrix, one of the major difficulties, as Dr. Tomlinson pointed out, would be the inevitable stray cross-coupling between the electrodes.

Earlier, the lecturer had demonstrated* electro-luminescent panels of different compositions giving blue, green and orange lights. A good red, he said, was very difficult to obtain chemically. Other problems to be overcome were the low light efficiency and slow response time of the phosphors to activation, but the efficiency in particular was being steadily improved.

In discussing the light amplifier itself, Dr. Tomlinson thought that it might possibly be incorporated in the screens of conventional television cathode-ray tubes. This would make possible lower velocity electron beams and hence lower e.h.t. voltages and reduced scanning power. However, one speaker who had seen an American light amplifier in operation said that, although the amplification and picture quality were both good, there was a considerable time lag in response which would be a disadvantage on moving television images.

* See April, 1955, issue, p. 153.

Drilled-Ferrite Switching Circuit

AN unusual form of construction for two-state switching and computing circuits recently developed at the Radar Research Establishment consists of a block of ferrite with small holes drilled in it, with transistors mounted on top so that their leads pass directly through the holes. This has arisen from the need for switching circuits which are small, reliable and economical in operation.

The idea of using small, square hysteresis-loop ferrite cores, with transistors to drive them from one state of remanent induction to the other, is becoming quite a well-known technique. Unfortunately it brings difficulties in manufacture in that the tiny cores—which are only 2mm across—require a great many turns of fine wire to produce the necessary switching m.m.f. from the small transistor driving currents.

The desirable simplification is a one-turn winding, but to attain this it would be necessary to have a core shaped like a thin-walled tube which would be capable of being switched by a low m.m.f. In the absence of such cores on the market, the nearest practical alternative that can be switched by low currents is the "magnetic cell" or narrow hole drilled in a block of ferrite. This principle was described by D. S. Ridler and R. Grimmond at the recent I.E.E. Ferrites Convention (see December, 1956, issue, p.596), and the R.R.E. device was actually disclosed by G. H. Perry in a discussion following the paper.

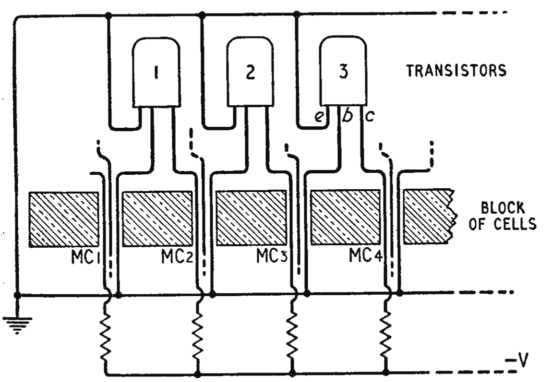


Fig. 1. Construction of transistor/magnetic-cell two-state elements arranged as a shift register.

Fig. 1 shows diagrammatically the construction of a group of the transistor/magnetic-cell two-state elements arranged as a shift register. The change of flux in each magnetic cell resulting from the switching action causes a current to be induced in a one-turn winding connected to the base of the associated transistor. The amplified current change at the collector is then passed through a single-turn winding of the next magnetic cell, which accordingly changes its state and applies an induced current to the next transistor . . . and so on. The action is initiated by a third single-turn winding in each magnetic cell, which serves to introduce shift pulses for moving the pattern of 0 and 1 digits along the length of the register.

The three pieces of 37 s.w.g. wire passing through each cell actually take the place of some 100 turns of 47 s.w.g. that are necessary on a conventional ferrite core performing the same action. The only disadvantage in using the magnetic cell is that it does not saturate. This means that the stored flux is largely dependent on the applied current, so that the two states are not so well defined and uncritical as in the ferrite toroidal core.

Equipments based on the transistor/magnetic-core element already give something like a 3,000:1 reduction in power consumption over valve circuits and about 100:1 reduction in size.

Student Exchange

SINCE the foundation of the International Association for the Exchange of Students for Technical Experience in 1948, nearly 29,000 students from 22 countries have taken advantage of the facilities provided by the Association whereby they can obtain practical experience abroad during the summer vacation. The 9th annual report records that in 1956 a total of 5,711 students went abroad under the scheme. By far the greatest number was from Germany (1,284) with Great Britain second (743). Sweden, who sent only 415 students abroad, received the greatest number (1,305) with Germany second (1,019). A total of 774 overseas students came to this country.

Although the radio and electronics industry is not given a separate classification—it is included in electrical engineering—it is obvious from the lists of the participating companies and research organizations in this country and abroad that a large number of them are in this field.

Details of the Association are obtainable from J. Newby, Imperial College, South Kensington, London, S.W.7.

WORLD OF WIRELESS

Organizational, Personal and Industrial Notes and News

Radio Shows

WE HAVE often deplored the proliferation of exhibitions catering for radio and its electronics offshoots. Will the situation be eased by the dates of some of the shows overlapping?

The Radio Industry Council has announced that this year's National Radio Show, which will again be held at Earls Court, London, will be from August 28th to September 7th with a preview for invited guests on the 27th. The static section of the S.B.A.C. Show at Farnborough, which has become the aeronautical radio exhibition, will be held from September 3rd to 9th with a preview on the 2nd.

The exhibition at which the marine side of the radio industry is usually well represented—the Engineering, Marine and Welding Exhibition—overlaps the National Radio Show still further, for it opens at Olympia on August 29th for fifteen days.

Audio Fair

ALL but four of the fifty-one exhibitors who have taken space at this year's Audio Fair will have demonstration rooms. The four-day fair will be held from April 12th to 15th, inclusive, at the Waldorf Hotel, Aldwych, London, W.C.2.

It is being run by Audio Fairs, Ltd., a non-profit-making company on which the following serve "on a purely voluntary basis": chairman, V. G. P. Weake (Pamphonic); vice-chairman, D. A. Lyons (Trix); M. L. Berry (Trix), L. H. Brooks (M.S.S.), J. W. Maunder (Vitavox), H. V. Slade (Garrard), G. E. Spark (M.S.S.), T. R. Threlfall (Goodmans).

DOCTORS Bardeen, Shockley and Brattain (L to R), who jointly received the 1956 Nobel Physics Prize in Stockholm in December, photographed when they worked together on the development of the transistor at Bell Laboratories.

G.E.C. Valve Policy

A FEW months ago the trade name of "Osram" valves was changed to "G.E.C." This foreshadowed a change in policy resulting from the acquisition by the General Electric Company of the share in the Marconi-Osram Valve Company formerly held by E.M.I.

In future, the M-O. Valve Company, which is now a wholly-owned subsidiary of G.E.C., will concern itself mainly with the manufacture of transmitting and special-purpose valves. Among the transmitting types will be klystrons, magnetrons, travelling wave tubes and backward wave oscillators, as well as valves for r.f. heaters. Receiving valves will include "reliable" and high-performance types in addition to audio amplifiers. Gas-filled valves such as thyratrons and xenon rectifiers represent an important side of the company's activities.

News in Morse

IT is some months since we published a schedule of the transmissions of English news bulletins prepared by the overseas press division of the Central Office of Information. For the bulletins to North America and the Far East an R.T.T. (printing radio telegraph) link, employing frequency-shift keying, is now used, and for a number of other areas the Hellschreiber method has taken the place of morse. There are, however, a number of areas for which morse is still used and below we give the latest schedule of these transmissions from Post Office stations. The morse speed varies from 22 to 28 words a minute.

Region	Times (G.M.T.)		Call	Freq. (Mc/s)
Distant Europe	Monday	0200–0430	GIQ25	5.365
	Tues. to Sun.	0300–0530		
Middle East	Monday	0200–0430	GBB33	13.595
	Tues. to Sun.	0300–0530		
Caribbean	Mon. and Fri.	1145–1215	GIB36	16.190
	Mon. to Fri.	1215–1315		
	Mon. to Fri.	1700–1830	GIB38	18.680
South America	Friday	2015–2130	GIN31	11.645
	Mon. to Sat.	0115–0230	GIS27	7.780
Africa	Mon. to Fri.	0915–0945	GAY40	20.100
	Monday	2015–2100		
South East Asia	Sunday	1915–2115	GAY27	7.447
	Mon. to Sat.	1715–1800	GAY33	13.665
	Mon. to Sat.	1815–2215	GAY27	7.447
	Mon. and Sat.	1600–1715	GAY33	13.665

PERSONALITIES

A.V-M. Raymond G. Hart, C.B., C.B.E., a member of Watson-Watt's Bawdsey team in 1936, has been appointed controller of engineering and equipment at the Air Ministry. In 1941 he went to the Air Ministry as deputy director of radar. He was subsequently concerned with the planning of the air signals in the invasion of Europe and became chief air signals officer at S.H.A.E.F.

Under the Department of Scientific and Industrial Research Act, 1956, which came into force on November 7th, a new research council has been formed in place of the former advisory council. **Dr. H. W. Melville,** F.R.S., is secretary of the council, and among the eleven members are **Professor P. M. S. Blackett,** F.R.S., (Imperial College) and **Dr. Willis Jackson,** F.R.S. (Metropolitan-Vickers).

R. H. Tizard, B.A., A.M.I.E.E., who had been superintendent of the Control Mechanisms and Electronics Division of the National Physical Laboratory, Teddington, since its formation in 1954, recently left to take up an appointment at the London School of Economics. He is succeeded by **Dr. A. M. Uttley,** who from 1940 until his present appointment was at the Radar Research Establishment (previously T.R.E.), Malvern. During the war he was concerned with the design of a number of synthetic trainers, and more recently was largely responsible for the functional design of TREAC, the electronic digital computer used in the Physics Department of R.R.E.

L. A. Woodhead, director and general manager of Cossor Instruments, Ltd., is the new chairman of the Electrical and Electronics Section of the Scientific Instrument Manufacturers' Association. He joined the parent company, A. C. Cossor, Ltd., in 1930 and during the war was in charge of the final test and inspection of valves and c.r. tubes at a large shadow factory.

William Culshaw, B.Sc., Ph.D., recently left the Radar Research Establishment, where he specialized in the field of microwave optics and later in millimetre wave magnetron development, and has joined the laboratories of the National Bureau of Standards at Boulder, Colorado. Dr. Culshaw, who joined T.R.E. in 1942, is in the N.B.S. Microwave Physics Section.

Dr. A. V. J. Martin, until recently editor of our French contemporary *Télévision*, has been appointed professor of electrical engineering at the Carnegie Institute of Technology, Pittsburgh, Pennsylvania.

L. S. Crutch, B.Sc., M.I.E.E., deputy chief engineer of Siemens Brothers and Company, which he joined in 1931, is appointed a director of the company. He has specialized in the development of telecommunication systems, and was for some years assistant chief engineer of Siemens' telecommunications department.

G. K. Nicholls, Assoc.I.E.E., has been appointed manager of the Cable and Wireless cable station and engineering school at Porthcurno, Cornwall, in succession to C. J. V. Lawson, recently appointed deputy engineer-in-chief.

I. C. I. Lamb, A.M.Brit.I.R.E., has been appointed engineer-in-charge of the recently opened I.T.A. station at Emley Moor, Yorks. Employed by the B.B.C. both before and immediately after the war, first as a maintenance engineer at Daventry and later in the research department, he subsequently went to Pye, Ltd. Last February he joined the I.T.A.

The announcement of the above appointment affords an opportunity to mention the engineers-in-charge of the first three I.T.A. stations. **W. Woolfenden** (Croydon), after service as a R.A.F. radar officer, went into industry for a short while before joining the B.B.C. in 1947. He has been with the I.T.A. since August 1955. **N. G. Payne,** A.M.I.E.E., was for 16 years on the maintenance staff of the B.B.C. before being appointed to Lichfield last February. **W. H. Jarvis,** A.M.I.E.E. (Winter Hill), was a marine radio officer from 1918 until 1935 when he joined the B.B.C. He was senior maintenance engineer at Alexandra Palace before joining the I.T.A. last April.

W. F. Harkness, who in the early days of broadcasting formed Electrical Appliances, Ltd., selling Eureka transformers, and after service with Cossor's went to the U.S.A. in 1939, has now retired and returned to this country. His address is 5, Dawson Place, London, W.2.

H. E. F. Taylor is the new secretary of the Radio Communication and Electronic Engineering Association in succession to Neill Christie. During the war Mr. Taylor was a lieutenant-colonel in the Royal Signals and was concerned mostly with long distance telecommunication projects. He has been a radio amateur for some 35 years and has operated in India with the call-sign VU2AT. His British call is G6HT.

L. Essen, D.Sc., Ph.D., A.M.I.E.E., who joined the National Physical Laboratory in 1929 and has been concerned with precise microwave measurements, in particular with the measurement of frequency and time, has been promoted to senior principal scientific officer in the scientific civil service. Dr. Essen, who is 48, recently developed a frequency standard, based on a resonance of the cæsium atom.

The B.B.C. has appointed **G. K. Drake** as engineer-in-charge of the television and v.h.f. sound broadcasting station at Blaen Plwy, Wales, and **B. M. Britton** as e-in-c of the Sandale, Cumberland, television station. Mr. Drake, who joined the Alexandra Palace television station in 1938, has been senior maintenance engineer at Wrotham, Kent, since 1949. Mr. Britton has been with the Corporation for 14 years.

T. P. Lynott, A.M.I.E.E., has been appointed chief engineer to Gardners Radio Ltd., of Somerford, Christchurch, Hants. Since 1947 he has been at the Atomic Energy Research Establishment, Harwell, as transformer design engineer, having previously been first with G.E.C. and then the directorate of instrument production at the Ministry of Supply. Mr. Lynott, who is 42, is chairman of the subcommittee of the Radio Components Standardization Committee of the Ministry of Supply dealing with transformers and chokes.

W. Grant, contributor of the article on page 33, studied at the Royal Technical College, Glasgow, for his B.Sc. in electrical engineering. During the war he was commissioned Electrical and Mechanical Engineer in R.E.M.E. He has since been undertaking research and development work and is at present with J. Stone and Company (Deptford).

OBITUARY

Air Commodore R. L. Phillips, C.B., C.B.E., who died on November 22nd at the age of 47, was associated with aeronautical radio for the major part of his career in the R.A.F. He had held the positions of Director of Radio and Director of Signals Policy at the Air Ministry.

The death is announced by the Canadian Department of Transport of **G. C. W. Browne,** retired controller of telecommunications, at the age of 66. He went to Canada from Ireland in 1912 and entered the Canadian Government Radio Service two years later. Since his retirement last year Mr. Browne had been acting as consultant to the Fowler Commission on Broadcasting in Canada.

George T. Clack, who for many years (until 1953) was honorary lecture secretary of the Television Society, died on November 17th at the age of 47. He had been with Bush Radio since 1939 where, as a senior laboratory engineer, he had been latterly primarily engaged on technical liaison work.

IN BRIEF

Receiving Licences.—During October the number of television licences current in the U.K. increased by 151,299, bringing the total to 6,291,072. The total number of broadcast receiving licences, including those for television and 310,301 for car radio, was 14,419,741.

Test transmissions from a 1-kW pilot transmitter will begin on March 1st from the site of the first **Scottish I.T.A.** station at Black Hill, Lanarks. The station will operate in Channel 10 (199.75 Mc/s vision and 196.25 Mc/s sound) although the carriers will actually be offset by −19.5 kc/s and −10.5 kc/s, respectively.

In preparation for the opening of the Scottish I.T.A. station at Black Hill, Lanarks., at the end of August, the programme contractors, Scottish Television, Ltd., are arranging a series of **weekly exhibitions** from February to June in the principal burghs to be served by the station. The Scottish Radio Retailers' Association is participating, and advice on the conversion of existing sets will be given to enquirers.

Lichfield Increased Power.—By adding 20-kW amplifiers to both the sound and vision transmitters at Lichfield the e.r.p. of the I.T.A. station was increased on November 23rd to 200 kW. Duplicate sets of transmitters were previously operated in parallel to bring the e.r.p. up to 100 kW. The spare sound and vision transmitters are now being kept as standbys in case of breakdown of the main equipment. All the transmitting equipment at Lichfield was designed and installed by Pye, Ltd.

The B.B.C.'s eighth v.h.f. sound broadcasting station, **Holme Moss,** was brought into service on December 10th. It is radiating a three-programme service on 89.3, 91.5 and 93.7 Mc/s with an e.r.p. of 120 kW. The six 10-kW transmitters (two for each service) were installed by Marconi's.

Four of the seven **gold medals** awarded to British manufacturers for goods displayed at the California State Fair, held in Sacramento in September, were won for radio and electronic equipment. Two of the medals went to Trix Electrical for their Trixonic amplifier 800 and record player A720, one to Pye for their "Leadsman" echo sounder, and one to Fonadek for their telephone amplifier. The medals were presented at a conference of the Dollar Exports Council by the Minister of Economic Affairs at the U.S. Embassy.

Sea-going trials of Gee (the Cossor hyperbolic navigational aid) have shown that sea-level ranges up to 200 nautical miles from coast chains can be relied upon. This was accomplished using the South Western chain which operates on a frequency around 25 Mc/s. The long range is attributed to tropospheric propagation.

Ferranti-Ekco Link.—Domestic radio and television receivers with the Ferranti trade mark will, in future, be marketed by a new company being formed by E. K. Cole, Ltd.

The scope of this year's Radio Society of Great Britain exhibition is to be widened considerably and the title changed to **Radio Hobbies Exhibition.** It will be held in October at Seymour Hall, Seymour Place, London, W.1, and is again being organized by P. A. Thorogood (G4KD), who is chairman of the London u.h.f. group.

JUBILEE of the invention of the triode valve by Dr. Lee de Forest is commemorated on this franking on a recent letter from the United States.

American Facts and Figures.—Dr. W. R. G. Baker, head of the General Electric Company's Electronics Park, at Syracuse, N.Y., in a review of the progress of the electronics industry, stated that one out of every forty jobs in the United States is in electronics, and that 75% of these did not exist ten years ago. Moreover, whereas the electrical industry in the States approximately doubles every ten years, the electronics industry is doubling every five or six years. Dr. Baker forecast that the use of semi-conductor equipment will increase 100% in the U.S.A. during 1957. Incidentally, during the past ten months the price of G.E. transistors has been reduced 35%.

"W.E." Editorials.—For nearly 30 years Professor G. W. O. Howe contributed editorials to our sister journal *Wireless Engineer* (now *Electronic & Radio Engineer*). An index to these contributions, including chronological, author and subject indexes, was compiled by Dr. A. J. Small, of the Department of Electrical Engineering at Glasgow University, some two years ago. An addendum bringing it up to date has now been prepared, and this, together with the original index (covering the period January, 1926, to March, 1955, the last of his regular editorials) is obtainable from Dr. Small, price 5s.

The Radio Trades Examination Board has issued a reminder that the closing dates for entries for this year's **Servicing Certificate Examinations** are January 15th for television and February 1st for sound receivers. Forms and regulations for the examinations, which will be held in May, are obtainable from the R.T.E.B., 9, Bedford Square, London, W.C.1.

Danish TV.—The information regarding Denmark included in the E.B.U. television map on page 605 of the December issue was incomplete. Three transmitters have been in use for the past eight months—Copenhagen (5 kW), Fyn, near Odense (5 kW) and Aarhus (2.5 kW).

"Audio-Frequency Response Measurements."—The equipment described under this heading in our December, 1956, issue was developed by the staff of Grundig (Great Britain), Ltd., in the company's laboratories.

Two nine-week courses on digital computers and on colour television will be held at the **Southall Technical College,** Middlesex, on Wednesday evenings, beginning January 16th. An eight-week course on experimental servomechanisms will also be held on Wednesday evenings, beginning February 6th. The fee for each course is £1.

A radio and television **maintenance and servicing** course will again be held during the spring term at the Wesley Institute, Wesley Road, London, N.W.10, on Monday evenings, beginning January 7th. (Fee £1.)

Transistors.—An evening course of eight lectures on transistor physics and transistor applications commences on Thursday, February 7th, at the South-East London Technical College, Lewisham Way, London, S.E.4. (Fee £1.)

Eight lectures covering the theory and practice of **electronic instruments** used in chemical analysis will be given at Battersea Polytechnic, Battersea Park Road, London, S.W.11, on successive Wednesday evenings commencing February 6th. (Fee £1.)

Most of the courses set out above deal with the technology of electronic communication. But, before information can be communicated, whatever the means, it must be clothed in words. To find the best words for the job becomes more and more difficult as the complexity of life increases. Managements of firms are realizing to an increasing extent that clear **presentation of information,** technical and otherwise, by their employees is important. Courses of instruction in various aspects of this subject are offered by Osmond Turner Mead Associates, of 3, Gower Street, London, W.C.1. A booklet describing the courses is issued.

BUSINESS NOTES

Vision and sound transmitters for the I.T.A. South Wales station are to be supplied by **Pye**. The equipment will be similar to that installed at Lichfield—20-kW vision transmitter and 5-kW sound transmitter with 5- and 1.25-kW standby equipment.

In the annual report of the **Solartron** group of companies it is recorded that sales increased from £152,300 in 1954 to £758,000 during the year ended last June. During the same period the staff has grown from 240 to 550, the average age being 33. A joint company (Industrial Automation Developments, Ltd.) has been formed by the Solartron Electronic Group, Ltd., and Scribbans-Kemp, Ltd., for research and development of automation in the food processing industries.

With the installation of **Pye** industrial television equipment at the airways terminal at Victoria, London, the announcer is both seen and heard. Pye industrial television equipment has also been installed by a firm of stockbrokers at the London Stock Exchange. It conveys by line to the company's offices a quarter of a mile away details of the constantly changing stocks and shares listed on the "board."

Within a few weeks of its announcement **Decca** true motion radar (TM 46) had been ordered for over one hundred vessels. Orders for all types of Decca marine radar now total more than six thousand—an increase of one thousand in about eight months.

A tour of U.K. ports is being undertaken by a demonstration caravan equipped with **Kelvin Hughes** marine gear, including the new Type 14 radar which has a slotted waveguide aerial. In January and February demonstrations will be given mainly in Northern Irish, Scottish and Welsh ports.

An order for the supply of fifty 10-watt f.m. mobile transmitter-receivers has been placed with **Marconi's** by the Metropolitan Police. Up to seven crystal-controlled channels are available within a 0.5 Mc/s section of the 70 to 100-Mc/s band.

A further fifty lifeboats of the Royal National Lifeboat Institution, making one hundred in all, are to be equipped with v.h.f. radio-telephone equipment by **British Communications Corporation, Ltd.**

The sales and service division of **F. C. Robinson and Partners,** at 122, Seymour Grove, Old Trafford, Manchester, 16 (Tel.: Chorlton 5366), will in future operate under the title of **McKellen Automation, Ltd.** The change does not affect the manufacturing operations at Cheadle of F. C. Robinson and Partners, of which F. P. McKellen (managing director of McKellen Automation) has been general manager for some years.

The sole manufacturing rights in Great Britain for the Bradford loudspeaker enclosure (of American origin) have been secured by **John Lionnet & Company** who have recently moved from the City to the West End. Their new address is 17, Charing Cross Road, London, W.C.2. (Tel.: Trafalgar 5575.)

An American patent (No. 254567), in addition to British patent No. 689695, has been granted to **Lustraphone** for their noise-cancelling microphone (Type VC52).

Two members of Mullard Overseas, Ltd., have joined **Mullard South Africa (Pty.), Ltd.** They are T. W. Hogg, a commercial executive of the radio division, and R. E. Collins, of the electronic tube division, who is to organize a technical service department.

A kit of relay parts comprising seven coils (500 ohms to 20 K ohms) and a variety of contact banks has been produced by **Stevenage Relays, Ltd.,** associates of W. H. Sanders (Electronics), Ltd.

A large-screen television receiver without loudspeaker but with headphones for individual patients has been installed by **Hadley Telephone & Sound Systems, Ltd.,** at the Royal Orthopædic Hospital, Birmingham.

Lithgow Electronics, Ltd., sole representatives in the U.K. and Eire for the products of the Hewlett-Packard Company, of Palo Alto, California, have moved from Harrow to 198/200, Bath Road, Slough. (Tel.: Slough 21292). At their new office facilities are provided for demonstrating such H.P. equipment as electronic counters, signal generators, and oscilloscopes.

With the opening of **Mullard's** new headquarters at Mullard House, Torrington Place, London, W.C.1 (Tel.: Langham 6633), the various departments of the organization which have been in a number of separate buildings will be under one roof.

OVERSEAS TRADE

Equipment for the provision of direct **radio-telephone links** between the islands of San Miguel and Terceira, and between Terceira and Faial, in the Azores group, is to be supplied by Marconi's. Initially the links will carry seven speech channels and six voice-frequency telegraph channels.

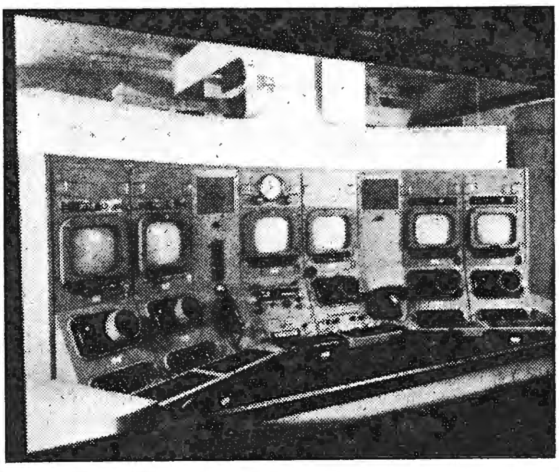
Electronic control equipment is being supplied by E.M.I. Electronics, Ltd., for an automatic conveyor system being installed by Geo. W. King, Ltd., of Stevenage, Herts., in the body-painting plant of a new Simca car factory at Poissy, France.

Solartron Incorporated has been formed to distribute and sell in the United States **electronic equipment** produced by the Solartron group in this country.

European Office.—Plessey International, Ltd., have opened an office at Singel 160, Amsterdam C, for the supervision of Plessey's interests in northern and central Europe.

This year's **International Liege Fair,** Belgium, will be held from April 27th to May 12th. Details of space available in the electronic section are obtainable from the U.K. representative, **R. C.** Liebman, 178, Fleet Street, London, E.C.4.

In order to overcome the delay caused by the recent New York dock strike Birmingham Sound Reproducers, Ltd., chartered planes to carry regular deliveries of **record changers** to the United States. American receiver manufacturers, who purchase $100,000 worth of B.S.R. equipment a week, volunteered to help defray the extra cost involved.



EASE OF CONTROL is the keynote of the whole installation at the two television studios at Riverside, Hammersmith, recently brought into use by the B.B.C. This is especially true of the lighting which is remotely controlled from positions adjacent to the sound, vision and production control rooms. Facilities for electronic effects, such as inlay and overlay, are also provided. Marconi camera control equipment is shown here.

Limiters and Discriminators

I—Wide or Narrow Bandwidth : Basic Equivalent Circuits : The Round-Travis Discriminator

By ***G. G. JOHNSTONE****, BSc.**

WE shall begin by considering the bandwidth required in a discriminator, more especially in view of the arguments put forward by Prof. Arguimbau and his colleagues in favour of wide-band discriminators.

If two f.m. signals interfere, they may be on the same carrier frequency (i.e., co-channel) or on nearby carrier frequencies (i.e., adjacent channel). Briefly Arguimbau maintains that in the presence of co-channel or adjacent-channel interference, the interfering signal will produce unwanted audio output even when the difference between the frequencies of wanted and unwanted signals is above the audible limit. The two signals add together to produce a composite signal which varies in amplitude and frequency according to the relative magnitudes and frequencies of the two signals. This is

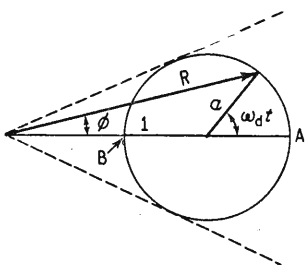


Fig. 1. Vector diagram of wanted signal (1) and interfering signal (a) *with a small frequency difference.*

shown in the vector diagram of Fig. 1, where the ratio of the amplitude of the unwanted signal to that of the wanted signal is $a:1$. The wanted-signal vector is assumed stationary and the unwanted-signal vector rotates at a relative angular frequency ω_d, which corresponds to the difference f_d between the frequencies of the two signals.

The magnitude of the resultant, R, varies between $(1 + a)$ and $(1 - a)$; this amplitude modulation can be removed by limiting and need not concern us further. The phase displacement (ϕ) of the resultant swings between the limits indicated by the dotted lines in Fig. 1. The phase displacement can be calculated and, since the instantaneous frequency shift is equal to $1/2\pi$ times the rate of change of phase angle, i.e., $f = \omega/2\pi$ and $\omega = d\phi/dt$ we can determine the frequency shift at any instant. The calculation is straightforward, but rather long, and it is sufficient for our purpose to note that the interfering frequency-modulated signal has the form shown in Fig. 2. The peaks at α occur when the vectors are in line as at A in Fig. 1; the peaks at β occur when the vectors have the position B in Fig. 1. The peak value of the frequency shift at α is given by $af_d/(1 + a)$ and at β by $af_d/(1 - a)$. Thus as the ratio of unwanted signal amplitude approaches that of the wanted signal a approaches 1 and the peak shift β becomes very large. The positive-going and negative-going excursions of the waveform of Fig. 2 have a different form but the areas included between the curves and the horizontal axis are equal, the mean resultant frequency shift is zero and there is no d.c. component in the output of the discriminator, provided that the discriminator is linear over the range of frequency excursion.

The period of the wave of Fig. 2 is $1/f_d$ and, if the frequencies of the two signals differ by more than the highest audio frequency, there will be no audible output under the steady state conditions postulated. If the frequency difference is less than the highest audible frequency, there is a heterodyne whistle; this is true whether the discriminator is "wide-band" or not.

To carry the argument further, suppose the difference between the frequencies of the two signals exceeds the highest audible frequency and the discriminator is narrow band. As the unwanted-signal amplitude approaches that of the wanted signal the ratio a tends to unity and the peak frequency shifts become progressively larger, tending to a limit of $f_d/2$ in one direction and infinity in the other. We shall concentrate on the peak at β because this is always greater than that at α. For an idealized narrow-band discriminator characteristic of the type shown in Fig. 3, the peaks at β are "clipped" as shown in Fig. 4. The areas under the positive-

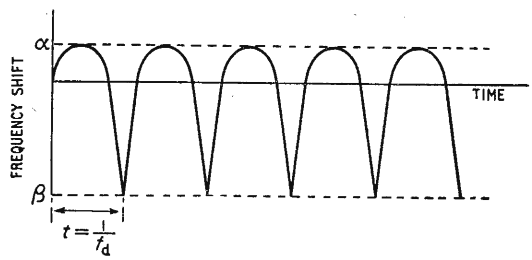


Fig. 2. Form of frequency modulation produced as a result of the conditions shown in Fig. 1.

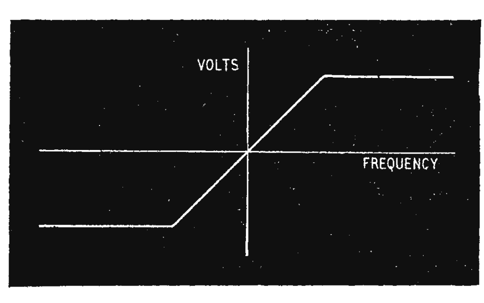


Fig. 3. Idealized narrow-band discriminator characteristic.

* B.B.C. Engineering Training Department.

for F.M. Receivers

A GREAT deal has been written about the performance of various types of limiter and discriminator for use in f.m. receivers, but much of this information is contradictory and the choice of a limiter and discriminator for a particular application may appear difficult, particularly to the newcomer to the subject. It is the purpose of this and subsequent articles to discuss the performance of the basic types of limiter and discriminator in an attempt to clarify the subject.

The discriminators to be discussed fall into six classes: (1) the Round-Travis (2) the Foster-Seeley discriminator (3) the ratio detector (4) the locked oscillator (5) the phase-difference comparator and (6) the counter. Types (3) (4) and (5) have a degree of inherent limiting action.

The types of limiter to be discussed comprise (1) the grid limiter (2) the anode limiter (3) the dynamic limiter and (4) the "clipper."

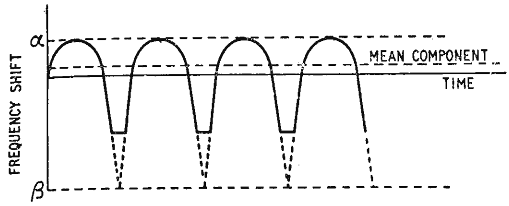


Fig. 4. Clipping of the frequency peaks by the characteristic of Fig. 3 results in a displacement of the average frequency.

going and negative-going portions of the waves are now no longer equal. There is a shift in the average frequency and a d.c. component in the output from the discriminator; it is shown in dotted lines in Fig. 4. If now the unwanted signal is modulated, its frequency swings about the mean value and the difference between the frequencies of the two signals alters correspondingly. The waveform of Fig. 2 now becomes that shown in Fig. 5(a); for comparison the graph of the frequency difference is shown at Fig. 5(b). If now the waveform of Fig. 5(a) is "clipped" as indicated by the dotted line, the d.c. component has superimposed "blips" as shown in Fig. 5(c). These have the same repetition rate as the modulating signal, and have components at multiples of the modulating-signal frequency. This represents cross-modulation between the two received signals accompanied by distortion. With a "wide-band" discriminator there is no clipping and this effect does not occur.

We may summarize the conclusions of the previous paragraphs as follows. In receiving co-channel signals some interference is inevitable because the difference between the frequencies of the two signals must, for part of the time, lie within the audio frequency range; this effect occurs whatever type of discriminator is employed. The peak heterodyne output is given by $af_d/(1-a)$ which decreases rapidly as a falls below unity and the stronger signal rapidly "swamps" the weaker as the ratio of the amplitudes of the signals a departs from unity; this is, of course, the well-known "capture" effect.

For signals on adjacent channels the difference between the frequencies of two carriers is always greater than the highest audible frequency; there is no cross-modulation if a wide-band discriminator is employed. This is illustrated in Fig. 6 which

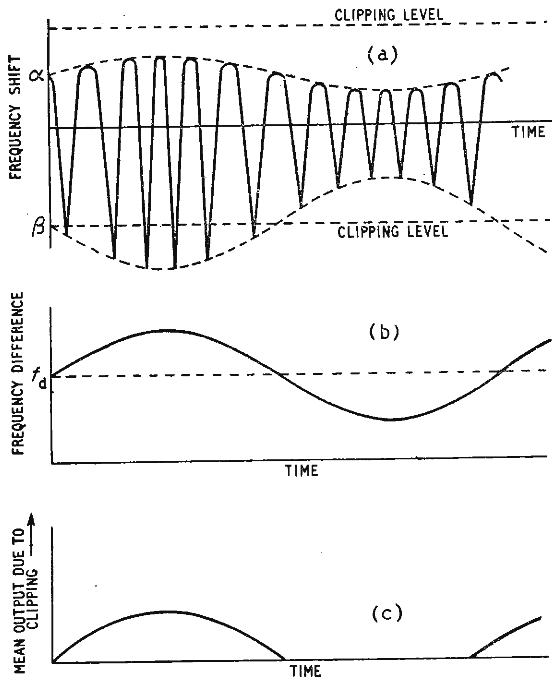


Fig. 5. (a) Waveform when the unwanted signal is modulated by a sine wave. The frequency difference is shown in (b), and the distortion product due to clipping is shown at (c).

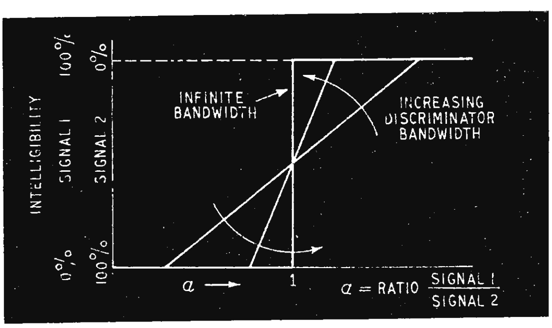


Fig. 6. Interference between signals on adjacent channels as a function of discriminator bandwidth.

shows that for an infinite bandwidth only the stronger signal is received even if its amplitude is only slightly greater than that of the other; but as the bandwidth is made smaller, the ratio of signal strengths for which interference is experienced becomes greater.

The behaviour of a discriminator toward ignition interference can be deduced by similar arguments.

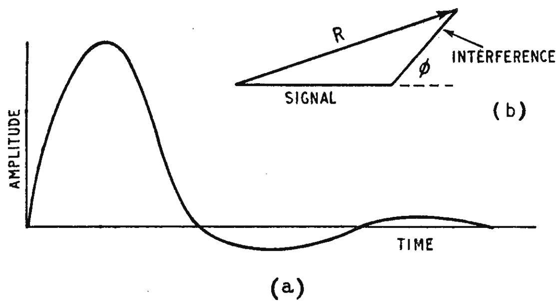


Fig. 7. (a) Waveform of i.f. output due to a pulse of interference and (b) vector relationship of signal and interference.

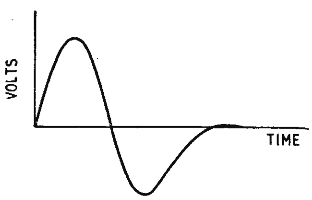


Fig. 8. Frequency shift (and hence discriminator output) due to interference of the form of Fig. 7(a).

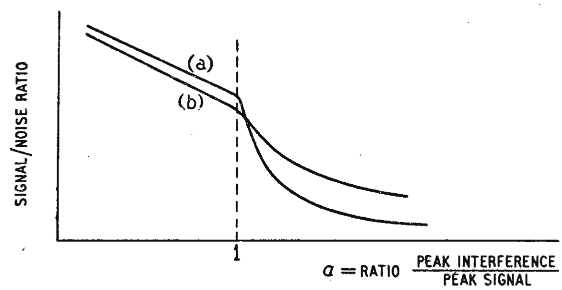


Fig. 9. Signal/noise ratio with impulsive interference for (a) wide-band and (b) narrow-band discriminators.

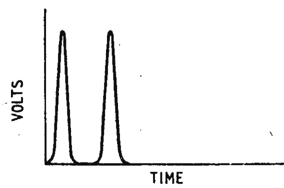


Fig. 10. Unidirectional double pulse produced in the discriminator output in some cases when the interfering pulse amplitude exceeds that of the carrier.

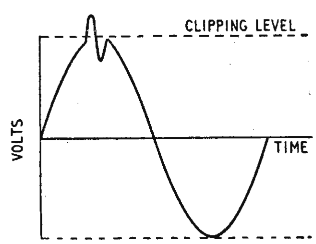


Fig. 11. When the interference pulse coincides with a peak of modulation, clipping may remove part of the pulse and increase noise.

The waveform of a pulse of interference is modified in the i.f. amplifier to a shape similar to that shown in Fig. 7(a). The shape of this pulse varies little with the source of the interference, but depends almost entirely upon the characteristics of the i.f. amplifier itself. The duration of the pulse is very short, approximately 7 microseconds for an i.f. bandwidth of 200 kc/s. The figure shows the envelope, which modulates a " carrier " at the centre frequency of the i.f. amplifier, which we shall assume equal to the signal carrier frequency. The signal carrier and interference carriers may have any phase angle with respect to each other, because the exact moment of incidence of the interference pulse is fortuitous. Thus the signal and interference carriers add as shown in Fig. 7(b); the phase angle between the carrier vectors ϕ has been arbitrarily selected. The interference signal vector grows and decays as shown in Fig. 7(a). Consequently, if the ratio of peak interference envelope to the peak carrier is small, the phase angle of the resultant follows a wave similar in shape to that shown in Fig. 7(a). The rate of change of phase angle, and hence the frequency shift then follow a curve of the type shown in Fig. 8. When the number of tuned circuits preceding the limiter exceeds four, the maximum value of the frequency shift due to the interfering signal is given approximately by $4aF$ where a is the ratio of the peak value of the interfering signal to that of the carrier, and F is the bandwidth measured between 3-dB points. The audible noise output is proportional to the net area under the frequency-shift envelope, and hence to a. However, the area under the positive-going excursion is nearly equal to that under the negative-going excursion and the net area is small. The spectrum of this output rises linearly with frequency, and the output has the sound of a " click." If a succession of constant-amplitude impulses are presented to the receiver, the magnitude of the output pulses varies with the relative phase angle between the carrier and the interfering signal at the occurrence of each impulse. If the amplitude of the interference signal is less than that of the carrier, a is less than unity and the signal-to-noise ratio falls linearly with a, as shown in curve (a) of Fig. 9. If the amplitude of the interfering signal exceeds that of the carrier, a is greater than unity and a new mechanism comes into play by which some of the output-signals have the form of sharp spikes, each pulse of ignition interference producing two spikes of the same polarity, as shown in Fig. 10. The net area beneath the curve is now no longer small. The spectrum of this waveform is level over the a.f. band and the output has the sound of a " pop." For such high-amplitude interfering signals, as the amplitude of the interfering signal is increased the signal-to-noise ratio falls abruptly and then levels off as shown in curve (a) of Fig. 9.

Consider the effect of reducing the discriminator bandwidth on impulsive interference of this type. If a is less than unity, and the signal is at one extreme of its frequency swing, one of the peaks due to impulsive interference in the discriminator output signal may be clipped as shown in Fig. 11. The net area increases and the signal-to-noise ratio is poorer than for a wide-band discriminator as shown in Fig. 9 curve (b). On the other hand, in the region where a is greater than unity, a reduction in discriminator bandwidth causes the amplitude of the spikes (Fig. 10) to be reduced and the signal-to-noise ratio is better than for a wide-band discriminator. Thus for impulsive interference a narrow-band discriminator is an advantage because the worsening of the signal-to-noise ratio in the region where this ratio is good in exchange for an improvement in the area where it is bad is in general desirable. Thus we may summarize the conclusions so far reached as follows:

(1) If the principal source of interference is co-channel and adjacent channel, a wide-band discriminator is best.

(2) If the principal source of interference is of the impulsive type, a narrow-band discriminator is best.

In this country co-channel and adjacent channel interference would not appear to present a serious problem, and hence ignition interference may be the principal type of interference to be overcome. In U.S.A., however, ignition interference is probably less troublesome than co-channel and adjacent-channel interference. Thus it would appear that British and American practice in discriminator bandwidth may tend to diverge, with a tendency in Britain to use narrow bandwidth discriminators.

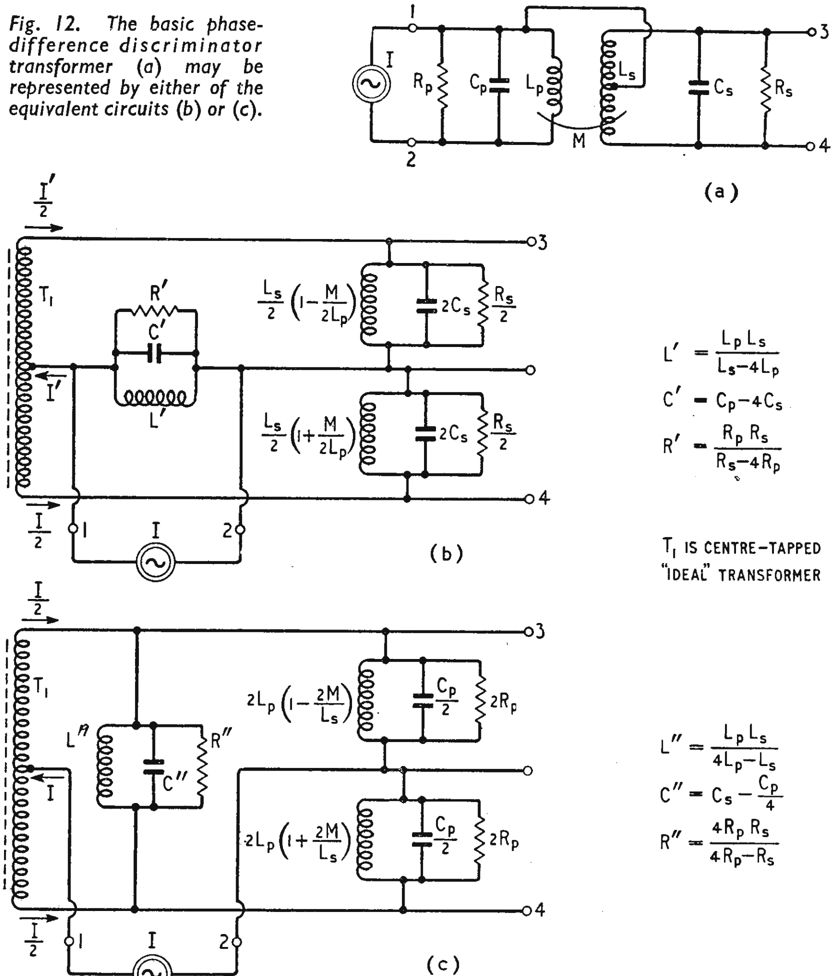


Fig. 12. The basic phase-difference discriminator transformer (a) may be represented by either of the equivalent circuits (b) or (c).

We shall now consider the performance of discriminators in detail and in the subsequent discussion we shall make extensive use of one or other of two equivalent circuit diagrams for the phase-difference discriminator transformer, Fig. 12(a), used in the Foster-Seeley discriminator and the ratio detector. These equivalent diagrams are shown in Figs. 12 (b) and (c), and their derivation is given in the Appendix. Depending on the constants of the original circuit only one of the two equivalents is physically realizable. The equivalent circuit for one special case reduces to two tuned circuits fed with equal currents, and resonant at frequencies equally displaced from the centre frequency of the transformer from which they are derived. Thus the Foster-Seeley and Round-Travis circuits shown in Fig. 13 have identical performances. This circuit transformation simplifies the analysis of the Foster-Seeley discriminator and the ratio detector and we shall analyse the performance of the Round-Travis circuit in detail in order to extend the results to the Foster-Seeley and ratio detector circuits.

Round-Travis Circuit. In this discriminator two

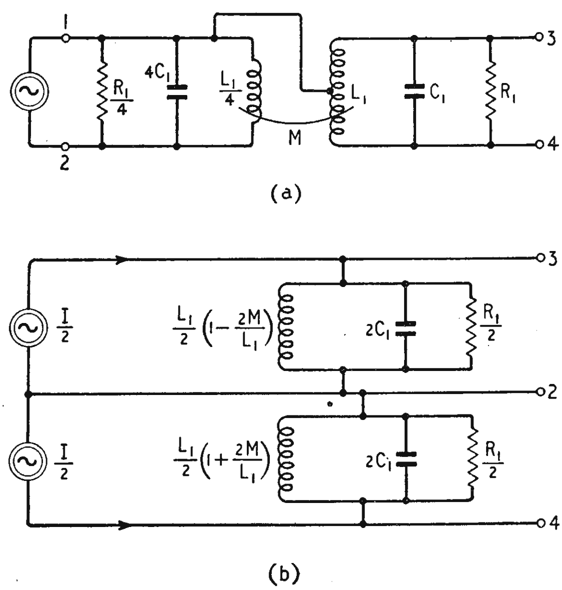


Fig. 13. Identical performances are given by these forms of (a) the Foster-Seeley and (b) the Round-Travis circuits

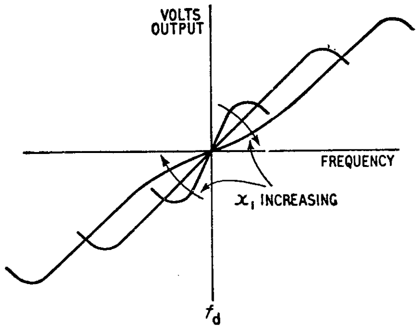


Fig. 14. Dependance of shape of discriminator characteristic on the value of x_1.

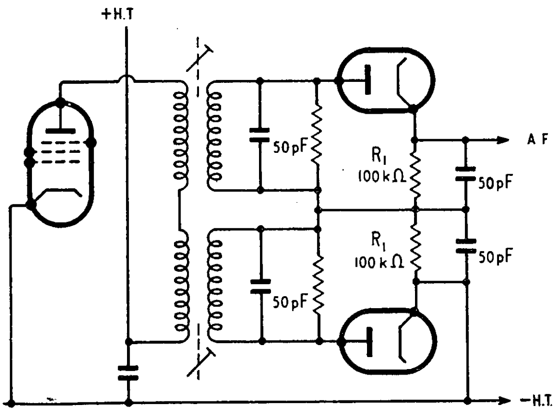


Fig. 15. Basic practical Round-Travis circuit.

tuned circuits are employed, one tuned to a frequency slightly above the centre frequency and the other tuned to a frequency an equal interval below the centre frequency. This circuit has appeared in a wide variety of forms, the variations being principally in the method of applying the signals to the two circuits. We shall consider the circuit in its general form, where the driving stage is represented by a constant current generator. as shown in Fig. 13.

We can write the response of a tuned circuit, comprising L, C, and R in parallel as

$$\frac{1}{Z} = \frac{1}{R} + \frac{1}{j\omega L} + j\omega C$$

In the frequency range near resonance (ω_0) we can write ω as ($\omega_0 + d\omega$), where $d\omega$ is small compared with ω_0. Using this substitution we can make the approximation that

$$\frac{1}{Z} = \frac{1}{R} + 2jd\omega C = \frac{1}{R} + 2j\frac{d\omega}{\omega_0} \cdot \frac{1}{\omega_0 L}$$

$$= \left(1 + \frac{2jd\omega}{\omega_0} \cdot \frac{R}{\omega_0 L}\right)/R$$

If we let $x = 2Qd\omega/\omega_0$, where Q is $R/\omega_0 L$, then

$$Z = R/(1 + jx)$$

in which x is a variable directly proportional to the frequency shift.

If one tuned circuit is tuned above the centre frequency and displaced by an amount $x = x_1$ and the other is tuned below and displaced by an amount $x = -x_1$ we can represent the impedance of the two circuits at any frequency in the neighbourhood of the centre frequency by $Z_1 = R/[1 + j(x - x_1)]$ and $Z_2 = R/[1 - j(x + x_1)]$ respectively.

The two diodes rectify the voltages developed across each tuned circuit independently, as shown in Fig. 15, and for 100% rectification efficiency, the output voltage is equal to the difference between the peak values of the voltage developed across each tuned circuit. If I is the peak value of the input current the output voltage is given by

$$E = IR[\{1 + (x - x_1)^2\}^{-\frac{1}{2}} - \{1 + (x + x_1)^2\}^{-\frac{1}{2}}]$$

A family of curves for various values of x_1, is shown in Fig. 14. These are the output-voltage frequency-shift curves for the discriminator, and ideally should have a linear region about the centre frequency. As shown in Fig. 14, for small values of x_1 the characteristic has continuous curvature and small peak separation. Larger values of x_1 give better linearity and greater peak separation, but above a critical value of x_1 the characteristic develops a kink near the centre frequency. Thus there would appear to be an optimum value of x_1.

The expression for E given above can be expanded as a series in ascending powers of x. The expansion is symmetrical about $x = 0$, and contains odd powers of x only. We can thus write

$$E = a_1 x + a_3 x^3 + a_5 x^5 \ldots$$

The first term represents the required output, i.e., an output varying linearly with frequency shift. The other terms indicate non-linearity, producing harmonic distortion and intermodulation in the output. This distortion can be minimized by making a_3/a_1, a_5/a_1, etc., as small as possible.

The evaluation of a_1, a_3, a_5 in terms of x_1 is straightforward but tedious. The values of the first three coefficients are:

$$a_1 = 2x_1(1 + x_1^2)^{-\frac{3}{2}}$$

$$a_3 = x_1(2x_1^2 - 3)(1 + x_1^2)^{-\frac{7}{2}}$$

$$a_5 = \tfrac{1}{4}x_1(8x_1^4 - 40x_1^2 + 15)(1 + x_1^2)^{-\frac{11}{2}}$$

From these expressions we have

$$a_3/a_1 = \tfrac{1}{2}(2x_1^2 - 3)/(1 + x_1^2)$$

and

$$a_5/a_1 = \tfrac{1}{8}(8x_1^4 - 40x_1^2 + 15)/(1 + x_1^2)^2$$

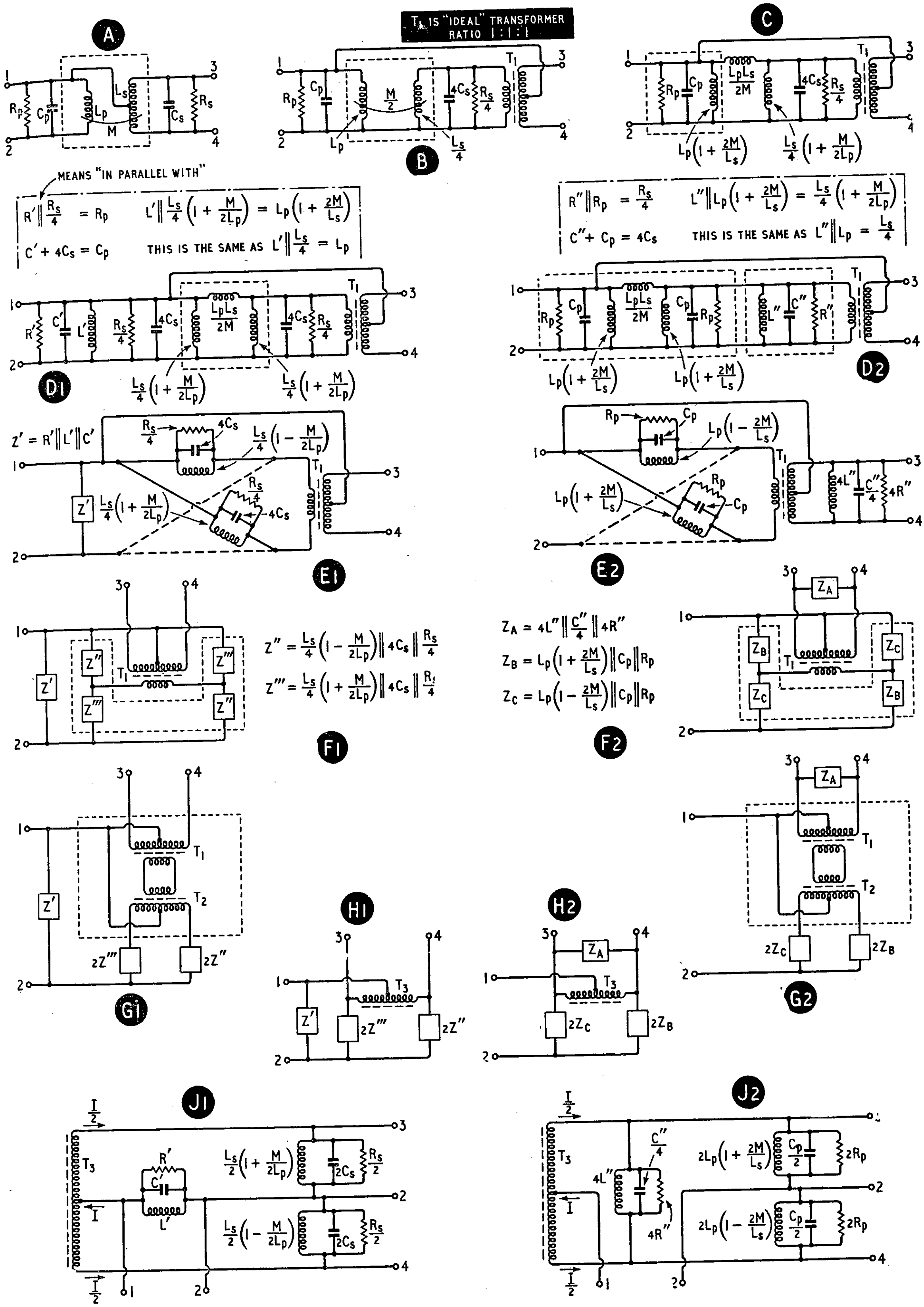
To minimize distortion, we can choose the value of

APPENDIX

THE derivation of the equivalent circuit for a phase difference discriminator transformer, Fig. A on the opposite page, is obtained by the successive manipulation of the portions enclosed by dotted lines. In Fig. B the secondary circuit comprising L_S, C_S, R_S is transferred to the primary side of the "ideal" transformer T1; this transformer has a centre-tapped secondary, providing the two voltages of opposite polarity in series with the primary voltage. In Fig. C, the "T" network is converted to "π" form. In Fig. D1 the terminations of the "π" network are made equal. If the terminations are made equal to the secondary components, the sequence follows through Figs. D1 to H1, and if to the primary components through Figs. D2 to H2.

In Fig. E, the "π" network is translated to a lattice by means of Bartlett's Bisection Theorem. Figs. F show Figs. E re-drawn. Figs. G show Figs. F re-arranged by the introduction of transformer T2, also of 1 : 1·1 ratio. Figs. H are Figs. G with transformers T1 and T2 combined into transformer T3. Figs. J show Figs. H re-drawn.

The derivation of these equivalent circuits is an extension of the treatment due to H. Marko (*Frequenz*, January, 1952).


A
B
C
T_1 IS "IDEAL" TRANSFORMER RATIO 1:1:1
MEANS "IN PARALLEL WITH"
$R' \| \frac{R_s}{4} = R_p$
$L' \| \frac{L_s}{4}\left(1+\frac{M}{2L_p}\right) = L_p\left(1+\frac{2M}{L_s}\right)$
$C' + 4C_s = C_p$
THIS IS THE SAME AS $L' \| \frac{L_s}{4} = L_p$
$R'' \| R_p = \frac{R_s}{4}$
$L'' \| L_p\left(1+\frac{2M}{L_s}\right) = \frac{L_s}{4}\left(1+\frac{M}{2L_p}\right)$
$C'' + C_p = 4C_s$
THIS IS THE SAME AS $L'' \| L_p = \frac{L_s}{4}$
D1
D2
$Z' = R' \| L' \| C'$
E1
E2
$Z'' = \frac{L_s}{4}\left(1-\frac{M}{2L_p}\right) \| 4C_s \| \frac{R_s}{4}$
$Z''' = \frac{L_s}{4}\left(1+\frac{M}{2L_p}\right) \| 4C_s \| \frac{R_s}{4}$
F1
$Z_A = 4L'' \| \frac{C''}{4} \| 4R''$
$Z_B = L_p\left(1+\frac{2M}{L_s}\right) \| C_p \| R_p$
$Z_C = L_p\left(1-\frac{2M}{L_s}\right) \| C_p \| R_p$
F2
G1
G2
H1
H2
J1
J2

x_1 which makes one of these ratios zero; it is usual to make $a_3 = 0$, because this is the dominant distortion-producing term for values of x less than unity. This gives $x_1 = \sqrt{1.5}$, and the expression for output voltage becomes

$$E = IR(0.62x - 0.055x^5 \ldots)$$

For this value of x_1, the useful extent of the characteristic is limited to values of x of less than unity. This is illustrated in the calculation below where it is shown that the distortion rises steeply for greater values of x.

To evaluate the distortion likely to be obtained with this circuit arrangement, we shall consider an input signal frequency-modulated by a signal of frequency f_a to a maximum swing of f_s kc/s on each side of the centre frequency. The value of x corresponding to f_s is represented by x_s and is given by $x_s = 2Qf_s/f_0$. Substituting the value $x_s \cos\omega_a t$ for x in the expression above gives

$$E = IR(0.62x_s \cos\omega_a t - 0.055x_s^5 \omega_a t \ldots)$$

We can expand $\cos^5\omega_a t$ by means of the identity

$$\cos^5\theta = \tfrac{1}{16}(\cos^5\theta + 5\cos^3\theta + 10\cos\theta)$$

which gives

$$E = I\,R[0.62x_s \cos\omega_a t - 0.0034x_s^5 (\cos^5\omega_a t + 5\cos 3\omega_a t + 10\cos\omega_a t)]$$
$$= IR\,[(0.62x_s - 0.034x_s^5)\cos\omega_a t - 0.017x_s^5 \cos 3\,\omega_a t - 0.0034\,x_s^5 \cos^5\omega_a t)]$$

The amplitude of the fundamental-frequency component is less for an ideal characteristic but the reduction is small and will be ignored, the values of x_s being limited to approximately unity. The percentage of third-harmonic distortion is then given by $\frac{0.017 \times 100}{0.62} x_s^4$, and the percentage of fifth harmonic is one-fifth of this figure. For $x_s = 1$, there is 2.7 per cent third-harmonic and 0.54 per cent fifth-harmonic distortion. The magnitude of the harmonic distortion is proportional to x_s^4, and thus falls rapidly if a lower value of x_s is considered. Thus reduced distortion can be obtained by using a lower value of x_s, but this in turn means a smaller output at the fundamental frequency.

With a broadcast signal, the frequency deviation is fixed at 75 kc/s. If it is desired to operate the discriminator with 75 kc/s corresponding to $x_s = 1$, the parameters of the circuit are determined by the relationship $x = 2Q\ df/f_0$. With $df = 75$ kc/s at $x = 1$, and a centre frequency (f_0) of 10.7 Mc/s, the value of Q is 71. The resonant frequencies of the two tuned circuits are given by $10.7\,(1 \pm \sqrt{1.5}/142)$ Mc/s, i.e., 10.7 Mc/s $\pm$ 92 kc/s. Such a discriminator would have very little margin to allow for oscillator-frequency drift and mis-tuning and a value $x_s = 1$ corresponding to 100 kc/s would be better. The circuit parameters are then $Q = 53$ with the resonant peaks at 10.7 Mc/s $\pm$ 123 kc/s. For such a discriminator at 75 kc/s deviation the third harmonic distortion is 0.84 per cent and the fifth harmonic 0.17 per cent. If we assume that the two tuned circuits each employ a capacitor of 50 pF, the dynamic resistance, $R = Q/\omega C$ of the circuits is approximately $53 \times 300 = 16\,k\Omega$. The input current, I, is the peak value of the fundamental-frequency component in the output of the preceding limiter stage; a typical value is 1 mA. The peak audio output is given by $0.62\,IR\,x_s$ and in the example chosen, x_s for 75 kc/s deviation is 0.75, giving a peak audio output of approximately 7.5 volts. The inductance required to resonate at 10.7 Mc/s with 50 pF is 4.45 μH; final adjustment of the resonant frequencies of the two circuits is made by means of dust-iron cores in the inductor formers. To secure the correct value of Q, the usual procedure is to design the coils for a higher value of Q than required and add damping resistors. The diode detectors provide part of this damping equivalent approximately to $R_1/2$, where R_1 is the value of each diode load resistor. The basic practical circuit is shown in Fig. 15; coupling windings to the two inductors are employed to isolate the tuned circuits from the h.t. supply. In practice, additional precautions are necessary to eliminate the effect of the primary circuit capacitance.

The Round-Travis circuit offers no real protection against amplitude modulation. The audio output is proportional to Ix, where I is the input current, and x is a measure of the frequency shift. If there is amplitude modulation the magnitude of I varies, but if $x = 0$, i.e., if the signal is at the centre frequency there is no output due to a.m. For any other value of x, i.e., if the signal is mistuned or frequency-modulated, there is an output due to the amplitude modulation. Because the output is proportional to Ix the a.m. and f.m. signals are multiplied together and there is complete cross modulation. Thus a circuit of this type must be preceded by a limiter stage.

(To be continued.)

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Residual Magnetism in Recording Heads

MOST tape recorders incorporate a long-time-constant smoothing circuit in the h.t. supply to the bias oscillator to ensure that the h.f. current in the record/replay head dies away slowly when the instrument is switched off. This is necessary because any "d.c." component of remanent magnetism in the head is known to cause an increase in background noise from the tape.

Unfortunately, the amplitude of h.f. bias for best results from the point of view of either low distortion or high recording level is much less than is necessary to drive the core to a state of magnetic saturation, so that if by any mischance the magnetic state is carried beyond the maximum represented by the bias the head will not be automatically demagnetized.

Fortunately, the head can easily be demagnetized by bringing up a strong (saturating) external alternating field and then removing it slowly. This field can conveniently be provided by a small 50-c/s transformer with an air gap arranged to coincide with the gap in the recording head, but it is not too easy to devise suitable means with conventional components, due to the smallness and inaccessiblity of most recording heads.

Wright and Weaire have recently developed a "defluxer" for this purpose in which projecting poles are arranged to give easy contact with the face of the record/playback head. The transformer is housed in a cylindrical case which falls conveniently to hand, and a press-button switch is provided for operation.

The "de-fluxer," which can also be used for selective erasure when editing tape records, costs £2 10s.

Portable Transistor Superhet

Home, Light and Third
With Currently Available Junction Types

By W. WOODS-HILL*

WHEN it was discovered that Standard Telephones & Cables were in quantity production of a 500-kc/s junction transistor, it occurred to the author that if one of these could be made to oscillate up to 750 kc/s, then a medium- and long-wave superhet could be designed along the lines of the American "cigar case" portables. These vary in size from 6in × 4in ×2in to 5in × 3½in × 1¾in.

The S.T.C. type TS3 transistors show a serious loss of gain above 450 kc/s, but if a low intermediate frequency of 275 kc/s is used, then sufficient gain can be obtained to drive the output stages. There is no problem about low-frequency amplification at 10 kc/s, and the 50 milliwatts required for normal room listening is within their power rating.

First attempts to make an oscillator of any frequency using some of the circuits described in American literature were disappointing. None of the six transistors available showed the slightest inclination to oscillate with the tuned circuit included in its emitter lead.

At last it was decided to revert to valve techniques, and a good beefy feedback winding was provided from the (output) collector to the oscillatory circuit. The last-mentioned had a direct (a.c.) connection back to the (input) base, and because the base has a rather low impedance this connection was tapped about ⅓ from the bottom. There was an immediate improvement, and oscillations were detected (a sound broadcast receiver does a good job as a wave-meter). Apart from altering the feedback tap on the oscillator coil so that it was just oscillating strongly enough at the high-frequency end of the band, and, of course, trimming off turns so that it covered the right frequency, no major alteration has been made to the circuit, which is shown in Fig. 2.

Various tapping points were provided on the coil at 20, 40 and 60 turns, and it was found that all the six transistors provided could be made to oscillate up to 750 kc/s by increasing the feedback (more turns), and two of them above 750 kc/s. The better one of these two was ear-marked for use in the receiver.

It is a good idea to build this oscillator on a tagboard and establish that it is functioning correctly and giving the right frequency coverage, rather than build the set "all in one go," because the parts used are small and difficult to alter in confined spaces.

The coil winding data in the table will give a frequency variation from 720 kc/s to 330 kc/s. This coverage, when used with a 275-kc/s i.f., will give the receiver a frequency range on medium waves from 330 + 275 = 605 kc/s to 720 + 275 = 995 kc/s. This includes the Third Programme at 640 kc/s, and the Home Service (Brookmans Park) at 900 kc/s.

Notice that this local oscillator is producing the 275-kc/s i.f. by oscillating below instead of above the signal as in the more conventional superhets. This will introduce a slight complication in the tracking arrangements—but a complication that is well worth while when it is realized that little selection of transistors is needed. In point of fact it is the fundamental reason why a superhet receiver covering most of the medium-wave band can be built using low-frequency currently available transistors.

The frequency changer is a quite straightforward stage consisting of a common (earthed) emitter amplifying stage (Fig. 1), where the signal at the aerial coupling winding is applied to the base, along with a small amount of r.f. from the local oscillator picked up by returning the bottom of the coupling winding to earth *via* two turns (L_3) wound round the earthy end of the oscillator coil.

Aerial Design

The ferrite aerial needs some explanation because it contributes greatly to overcoming the trouble in tracking.

Very roughly it can be said that the amount of signal picked up by a ferrite aerial is proportional to the bulk of ferrite enclosed by the tuning coil. That is to say, for maximum signal strength measured at the coupling coil the correct number of turns to resonate with the tuning capacitor should be loosely

*The British Tabulating Machine Company.

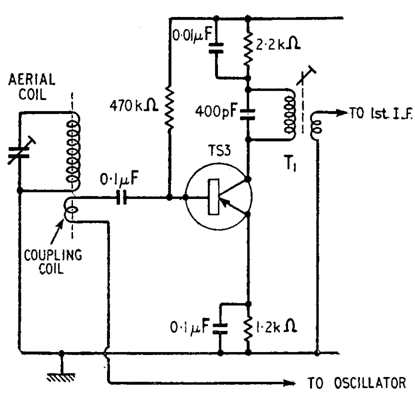


Fig. 1. Frequency changer circuit, showing input from oscillator.

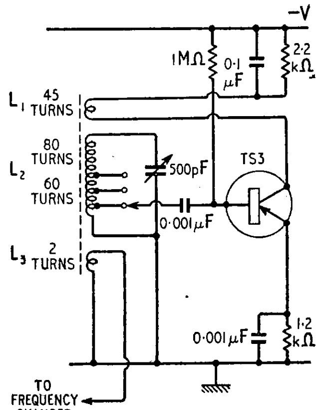


Fig. 2. Oscillator circuit with output to frequency changer.

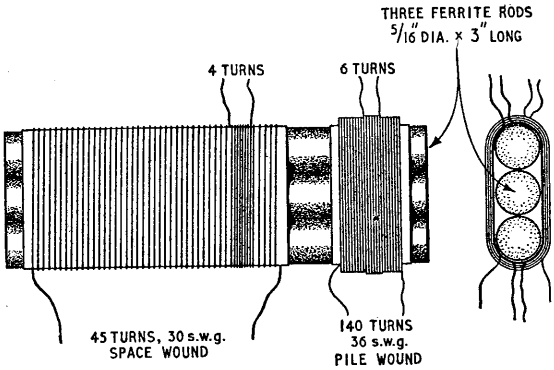


Fig. 3. Construction of the ferrite rod aerial, showing numbers of turns.

wound over the whole length of the rod. To obtain maximum bulk of material without excessive length three ferrite rods are stacked one above the other.

A certain price has to be paid for this increase in signal, inasmuch as the Q and selectivity of the circuit will be considerably reduced. On the other hand, to simplify tracking problems (which in this case can be stated as the aerial circuit failing to stay accurately in step with the local oscillator), what is wanted *is* a broad-band low-Q circuit which will ensure the signals are not seriously attenuated despite mistuning of the aerial circuit.

The ferrite rod aerial consists of three Ferroxcube rods of $\frac{5}{16}$in diameter (Mullard type FX1495) and three inches long stacked one above the other and bound with Sellotape to hold them in place.

As shown in Fig. 3, the medium-wave winding consists of 45 turns of 30 s.w.g. insulated copper wire wound reasonably loosely, starting $\frac{1}{4}$ inch from one end and occupying about 2 inches. This forms the tuning coil. The coupling winding consists of 4 turns of the same gauge wire wound in between the turns of the tuning coil, starting about 5 turns up from the bottom.

The last winding is the long-wave coil and is pile wound to cover about half an inch of rod right on the end farthest from the m.w. coil. This winding consists of 140 turns of 36 s.w.g. enamel- and cotton-insulated copper wire. The coupling coil here consists of 6 turns of the same gauge wire.

All these windings should be temporarily held in place and prevented from unwinding by small pieces of Sellotape stuck over the first and last turns of each.

As the electrical properties of ferrite rod vary slightly from sample to sample, adjustments to the number of turns may be necessary to optimize the frequency coverage and the rod should be tested before finally binding the whole length from end to end with tape. If the coils have been wound on a former of cartridge paper, so that the rods are a loose fit inside, then final adjusting of the tuning and tracking can be done by moving the coils along the rods. The centre of the rods gives maximum inductance.

The aerial has been made this shape to fit across the case of the receiver, and as it is possible that lengths this size may not be available, a word on how to cut the ferrite will not be out of place. The rod to be cut should be placed on a flat surface and held by hand. A nick should be made with a hack-

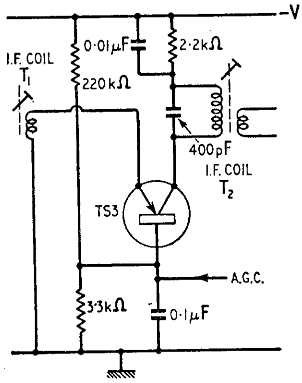


Fig. 4. An i.f. stage, showing the a.g.c. connection.

saw or Abrafile on opposite sides and then the rod broken simply by attempting to bend it by hand. This material is extremely brittle and any attempt to hold it in a vice or pliers will usually cause it to break at any other place but that required.

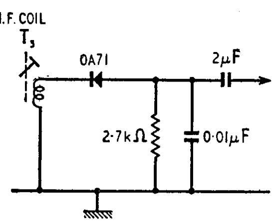
Coming now to the i.f. section, the frequency of 275 kc/s chosen was the result of a compromise between a high i.f. to reduce whistles to a minimum and a low one that would give a useful gain from the transistors (which is well down at 500 kc/s).

The transistors were tried in a common (earthed) emitter circuit, which is theoretically capable of higher gain per stage than the common-base circuit finally chosen, but so much trouble was encountered due to instability (feedback within the transistor) and so many components were needed to neutralize this tendency to instability under varying battery voltages and temperature changes, that the loss in gain was considered a small price to pay. The circuit adopted is shown in Fig. 4.

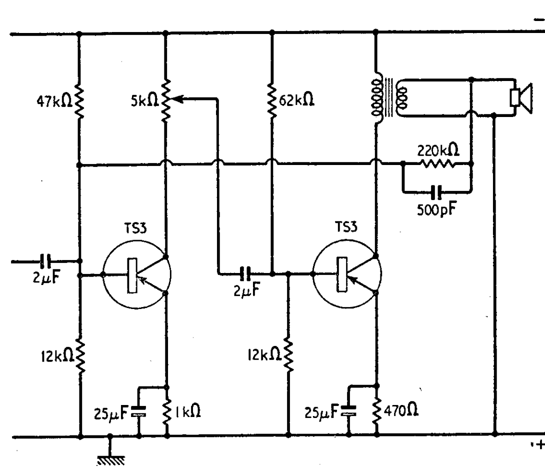
I.F. Transformers

Because the input impedance of the transistors is so low compared with their output impedance, to obtain a correct match from stage to stage the i.f. transformers must give a ten-to-one reduction in

Fig. 5. Germanium-diode detector circuit.



Below: Fig. 6. Audio amplifier and output stages.



turns from primary to secondary. In fact the primaries have 330 turns while the secondaries have 33 turns. A slight increase of stage gain can be obtained by increasing the secondary turns, but above this excessive damping of the previous i.f. resonant circuit may occur and result in a decrease in gain. The secondary should be wound on the former first and the primary on top.

The detector circuit, shown in Fig. 5, is quite straightforward, consisting of a point contact germanium diode, Mullard OA71, connected as a half-wave rectifier.

Because the input impedance to this stage is considerably higher than that of the common-base i.f. transistor stage, the secondary winding of the third and last i.f. transformer is increased from 33 turns to 50, so that a higher stage gain is available on this than the previous ones.

It should be noted that the 2.7-kΩ diode load is returned to earth, but in the full circuit diagram (Fig. 7) it is returned to the base of the first i.f. transistor to provide a.g.c. action. Whilst testing the i.f. stages it is best to return the resistor to earth because confusing results can be obtained with strong signals.

A good way of adjusting the i.f. section is to build it as a separate exercise, complete with detector, and if no signal generator or oscilloscope is available, to connect a pair of headphones to point X and earth in Fig. 5, connect an aerial *via* a 25-pF capacitor to the first i.f. tuned circuit, and trim up on any available signal or noise within the range of the i.f. trimming (about ± 25 kc/s).

The low frequency part of the receiver consists of two common-emitter transistor stages RC-coupled from the diode detector, with negative feedback applied at high and low frequencies.

Notice in Fig. 6 that the coupling capacitors should not be reduced much below 2 μF or a serious loss at low frequencies will result. The 5-kΩ potentiometer used as a volume control forms part of the first amplifier collector load.

The negative feedback is taken from the speech coil of the loudspeaker, so that it covers distortion introduced by the loudspeaker transformer as well as that from the two low-frequency stages. Connection of this negative feedback should be left to the last, and if oscillations occur the sense of the transformer speech-coil winding should be reversed.

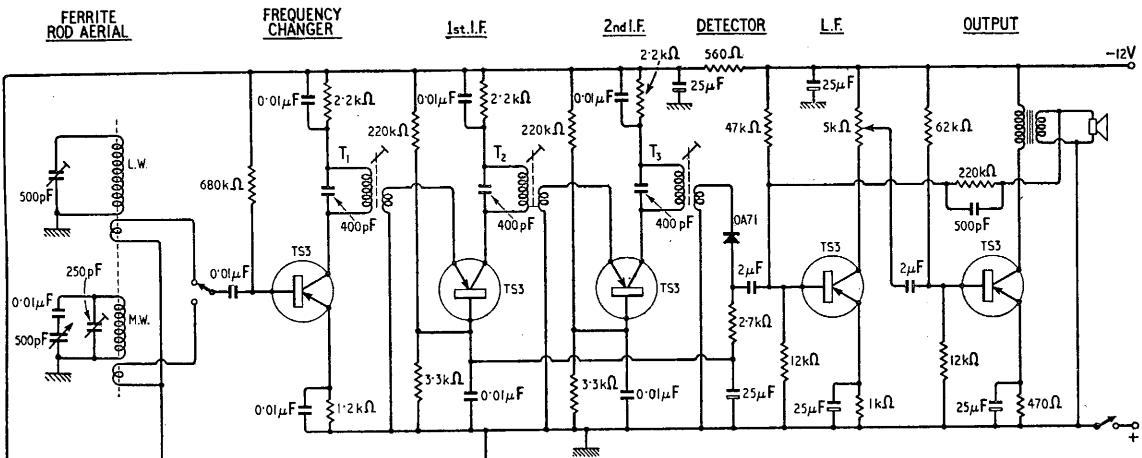
A miniature speaker transformer of the type usually sold with the 2½-in and 3-in speakers gives a tolerable match to the output stage as soon as the negative feedback is connected, but those patient enough can dismantle this and increase the secondary turns by 20% to improve the match.

Complete Circuit

The complete design has been broken down into four separate stages because, to anyone tackling transistors for the first time, the effects caused by wiring mistakes or faulty components are unfamiliar, and can lead to the disconnection of each main portion as the only means of identifying whence the trouble originates, whilst in a thermionic-valve superhet the nature of the fault gives an immediate clue.

Notice in Fig. 7 how the long-wave coil of the ferrite rod aerial is brought into circuit by the coupling coil and the switch. When this winding is brought into circuit no alteration has to be made to the oscillator. A quick look at the frequencies involved will show why it is not necessary.

If reception is required on long waves of, say, the 200-kc/s Light Programme (which is the main reason for providing this range), then if the local oscillator is tuned to 475 kc/s, it will beat (on the upper side this time) with the 200 kc/s, to once



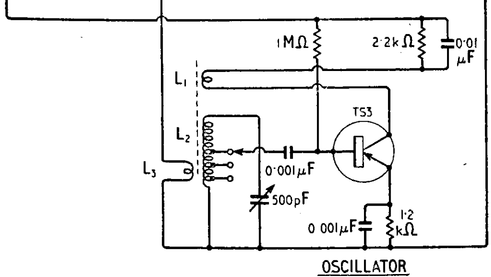


Fig. 7. The complete circuit diagram, assembled from the previous diagrams Figs. 1 to 6.

again provide the 275 kc/s intermediate frequency. The trimmer connected across the coil should be trimmed for maximum signals on the 200-kc/s Light Programme.

Coming now to the actual construction, the circuit was first built on a standard double-row tag strip with 30 tags down each side. As all resistors were

COIL WINDING DATA	
Oscillator Coils	
Former:—	Aladdin ¼in diam., 1in long with dust core.
L_1 ..	45 turns 36 s.w.g. cotton covered, wound on first.
L_2 ..	140 turns 36 s.w.g. cotton covered, tapped at 20, 40 and 60 turns, pile wound next.
L_3 ..	2 turns 36 s.w.g. cotton covered, wound on last.
I.F. Transformers	
Former:—	Aladdin ¼in diam., 1in long with dust core.
T_1 & T_2 ..	Secondary: 33 turns 36 s.w.g. cotton covered, single layer, wound on first. Primary: 330 turns 36 s.w.g. cotton covered, pile wound on top.
T_3 ..	Secondary: 50 turns 36 s.w.g. cotton covered, single layer, wound on first. Primary: 330 turns 36 s.w.g. cotton covered, pile wound on top.

1/8 watt (mainly Erie type 16) and the largest fixed capacitor was a 25-μF miniature cathode bypass, no component short of the tuning capacitor needed any other support than that provided by soldering it into circuit. This enables all the units—i.f. stages, oscillator, frequency changer, output—to be tested under portable conditions before attempting to miniaturize.

Incidentally, if one decided to stop at this stage of development, having, say, built the receiver on two 6in tag strips, it would make a handy and economical portable, especially if a push-pull output stage using Mullard OC72 transistors were added.* Such an output stage would provide ample output to drive a 6in loudspeaker.

*See "Transistors for the Experimenter" booklet, obtainable free from Mullard. Note that the OC72s require only 6V. Suitable transformers can be obtained from Sobell.

It is not possible to be dogmatic about the final form of construction possible because this depends so much on each person's access to materials and miniature components. It can be stated, however, that the author has built two versions of the circuit shown. The first is constructed around the magnet of a 6-in loudspeaker utilizing full-size components throughout, with a push-pull output stage. This set is in constant use, and has a cabinet measuring 7in × 7in × 3in. The power supply consists of three flat 4.5-V torch batteries connected in series, and as these are designed to supply up to 300 mA to a bulb, the 25 mA average current drawn by the set is a very light load and many months of use can be obtained from three-shillings-worth of batteries.

The second version of the set is in a case measuring 5in × 3in × 2in. The loudspeaker is a 2½-in Elac type and the supply battery is a 15-V hearing-aid (or flash-gun) type which drops to about 10V on load. Needless to say, this is the single-ended version of the circuit.

The author would like to advise readers again to be sure they have mastered the intracacies of the circuit before attempting to build it in a 5in × 3in case, as the components will have to be packed side by side and sometimes in layers to get them all in.

Finally, the author was not in a position to evaluate the performance of the set in technical terms, but the following remarks will give readers a clue. Overloading of the output stage was possible in the London area on both the Third and Home Services, so long as the receiver was not used in a metal-framed building. The long-wave Light Programme was considerably weaker, presumably because the transmission originates in Droitwich. On the other hand, reception on this long wave was more consistent and suffered less from the screening effects of buildings. The volume level is more than adequate for listening in a room with no background noise, but if one wishes to hear the set above, for example, the conversation in a crowded room, then it is worth while adding the push-pull output stage.

Resistance - Current - Voltage - Power Nomogram

*By B. E. JACKSON, B.Sc.**

PROBLEMS involving the relationships between the parameters resistance, current, voltage and power are constantly having to be worked out in electrical and electronic work. In most cases speed rather than accuracy is required. Therefore, a nomogram or a slide-rule-type calculator can profitably be employed.

Nomograms have had limited usefulness in this field in the past because (*a*) they have related only three of the four variables or (*b*) two settings of the rule have been required for a complete solution of the problem.

The nomogram presented here has the advantage that only one setting of the rule on the two known parameters is required to give the solution of the two unknowns.

For the convenience of those engaged in electronic work the resistance scale is laid out in "preferred" values of resistors in addition to the ordinary logarithmic scale divisions.

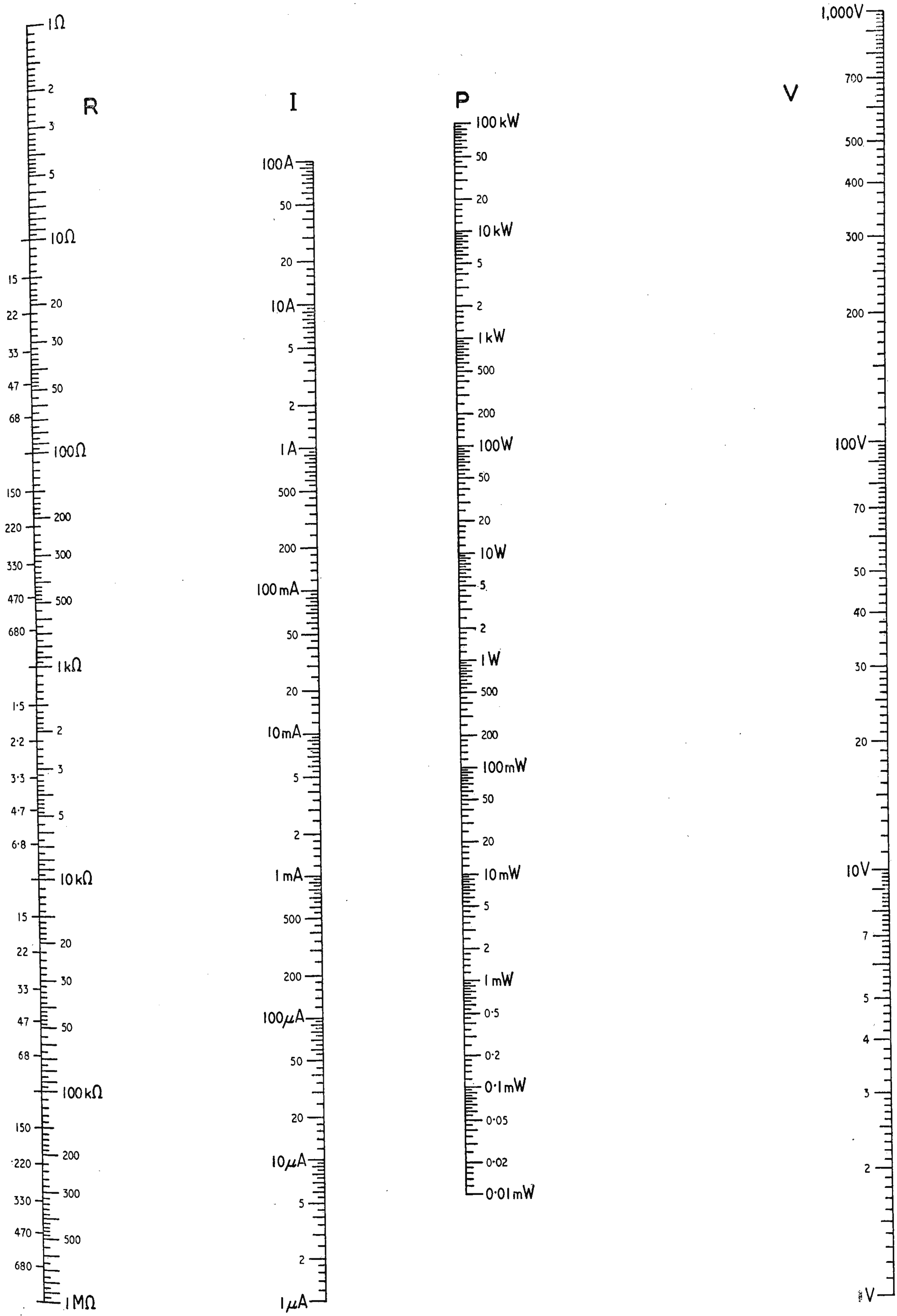
Of course, the nomogram can also be used in place of a slide rule for the occasional multiplication or division of numbers not connected with voltage, resistance, etc. For example, the product of two numbers can be read off the V line by setting the rule over the two numbers on the R and I lines respectively.

The use of the nomogram is so straightforward that only one example need be given:—

Q.—What is the current passing through a 10-kilohm resistor and what is the power dissipated when the voltage across it is 150 V?

A.—Lay a rule across the nomogram intersecting the R line at 10 kilohms and the V line at 150 V. Read off the current from the I line equal to 15 mA and the power off the P line equal to 2.25 W.

* Dominion Laboratory, Department of Scientific and Industrial Research, Wellington, New Zealand.


R
I
P
V
1Ω
10Ω
100Ω
1kΩ
10kΩ
100kΩ
1MΩ
100A
10A
1A
100mA
10mA
1mA
100μA
10μA
1μA
100kW
10kW
1kW
100W
10W
1W
100mW
10mW
1mW
0·1mW
0·01mW
1,000V
100V
10V
1V

Is Radio Propagation

Non-Reciprocity and Circuit Asymmetry in Short-Wave Communication

THE old-time radio operator used a simple rule for his guidance in the establishment of communication with a distant station: "If I can hear him, he can hear me." To that, of course, should have been added a proviso regarding the necessity for exact similarity between the radiated power of his and the distant station, but, as it was, his rule often worked. Was it then based upon any scientific principle, or was it merely a piece of professional folklore? Some interesting experiments have recently been carried out which throw some light upon this, until lately, largely unsettled question.

Reciprocity in Radio Communication.—The meaning of the reciprocity theorem, as applied by Carson[1] to radio communication, may be expressed as follows: "If an electromotive force of a certain magnitude inserted in one aerial causes a current to flow at a certain point in a second aerial, then the same voltage applied at this point in the second aerial will produce the same current, both in magnitude and phase, at the point in the first aerial where the original voltage was applied." According to the statement of reciprocity by Sommerfeld[2] this will happen regardless of the electrical properties and geometry of the intervening media and of the form of the two aerials. From this we should expect radio transmission in opposite directions over a distance to be truly reciprocal, as is the case with electrical phenomena in other forms of network, provided that no change occurs in the intervening medium with time. There is, in fact, no reason to doubt that the reciprocity theorem is true when applied to ground-wave transmission, and it is only when sky-wave transmission occurs, where propagation is *via* an ionized medium in the presence of a magnetic field (the earth's), that it does not really hold. And in this latter case, which is that obtaining for all long-distance short-wave communication, though the possibility of non-reciprocal effects was realized by Carson, it does not seem to have been confirmed by experiment until recently.

It can be shown, however, that in certain special cases the theory of reciprocity should not hold. One of these is that where the wave travels through an homogeneous ionized medium along a magnetic meridian; i.e., along the direction of the magnetic lines of force, in which case the polarization of the wave twists in an anti-clockwise direction as it travels along, and, moreover, twists in the same direction whether going or coming, so to speak. The direction of twist is determined by the direction in which the magnetic force is acting, and not by the direction of propagation of the waves. In this case, if the direction of polarization of the wave when it leaves the transmitting aerial is the same in both the "go" and "come" directions then the propagation is still reciprocal, but if it is different in the two cases propagation is not truly so, there being a phase change at one end as compared with the other. It is even possible to find a case where the polarization changes are such that propagation is only possible at all in one direction. But these special cases may possibly have small significance in practical communication.

Of course if the "go" and "come" paths by way of the ionosphere were different in practical cases, as has sometimes been postulated, then the possibility of non-reciprocal effects would become more obvious, for there could be a differential factor in the ionospheric absorption for the two directions. However, it does not seem likely that waves travelling in opposite directions would, in fact, traverse different paths, and, therefore, that there would be differences in wave attenuation due to absorption.

In short, the possible effects of non-reciprocity in long-distance short-wave communication are by no means easy to assess, though, from operational data which has accumulated over the past several years, there is now no doubt at all that there can be differences in the performance of a radio circuit in the two opposite directions when the transmitting and receiving equipments at the two ends are similar. In other words, the rule of the old-time radio operator is not, essentially, a good one.

Tests for Reciprocity.—An experiment made to test the reciprocity of the 420-mile transmission path between Slough and Inverness by the D.S.I.R. has been described by Meadows[3]. Elaborate precautions were taken to ensure that the observed effects were due to the intervening medium, and not to any apparatus contributions. Pulse transmissions were used on a frequency of approximately 5.1 Mc/s, these being transmitted from and received at both terminals, the same aerial at each end being used both for transmitting and receiving, being switched from transmitter to receiver at the pulse repetition frequency. The received pulses were displayed on cathode-ray tubes, and the Inverness display was relayed by line to Slough, so that the two patterns could be visually compared there, and differences between the fading patterns of the ordinary E and F ray echoes observed. This was considered to be a sensitive test for non-reciprocity.

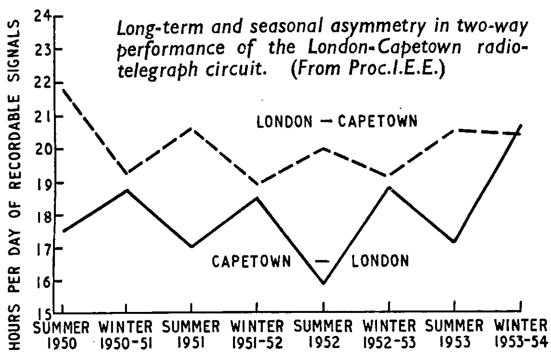
During about 15 hours of observation spread over 13 days definite non-reciprocal effects were observed for only about 1 per cent of the time. It was considered that this being so for this short path more pronounced non-reciprocal effects might occur on long-distance circuits, though probably they would be of short duration.

The results of a test for non-reciprocity over long-distance circuits are given by Laver and Stanesby[4], who describe those obtained from a carefully controlled experiment conducted by the Post Office Engineering Department. The tests were made separately between the United Kingdom and the United States and between the United Kingdom and Australia on frequencies between approximately 11 and 14 Mc/s. At each end of these two circuits a single aerial was used, switchable to a transmitter or to a receiver tuned to the same frequency. Un-

Always Two-Way?

By T. W. BENNINGTON*

modulated carrier was transmitted alternately for two minutes from either end of the circuit. The output signals from the receivers were recorded and the results were expressed in terms of circuit loss, the aim being to obtain the loss difference between transmission over each circuit in one direction and that in the other. At times there was no significant loss difference, but quite often for periods of a few hours loss differences, indicating non-reciprocal transmission, did occur. On the average the loss was greater for transmission from the United Kingdom to the United States and to Australia, than for transmission from those two countries to the United Kingdom. At times the loss difference for transmission in the opposite directions rose to values of the order of 5 to 10 dB. The reality of the test



Long-term and seasonal asymmetry in two-way performance of the London-Capetown radio-telegraph circuit. (From Proc.I.E.E.)

results seems to be well proved by the fact that on some days no appreciable loss difference occurred, though on the previous days, with test conditions exactly the same, considerable loss differences occurred persistently.

These two valuable experiments, one over a relatively short and one over two long transmission paths, do therefore seem to prove that non-reciprocal effects are of some importance in long-distance communication via the ionosphere. They do not fully show, however, to what phenomenon the non-reciprocal effects are due, nor indicate the long-term significance of such effects. We may perhaps tentatively conclude that true non-reciprocity may not be the *major* cause of the operationally observed differences in long-distance circuit performance in opposite directions.

Circuit Asymmetry.—It has for some long time been realized that, since the distribution of atmospheric noise is not uniform over the earth's surface, but tends to be greatest in the equatorial land regions, and to vary at all places with time of day and season, the signal/noise ratio for a signal of given field-strength must vary for different geographical locations. That being so it follows that, quite apart from the effects of non-reciprocity, the performance of a radio circuit would not necessarily be the same in two opposite directions if judged on the basis of the signal/noise ratio at the receiver inputs. Or, to put it into operational terms, the percentage of time for which a long-distance radio circuit was "commercial" or "uncommercial" would not necessarily be the same at the two opposite circuit terminals even if the transmitting and receiving equipments were identical. As has been said, such circuit performance differences have long been noted, and more light has now been thrown upon the subject by a recent study made by Humby and Minnis[5]. In order to distinguish it from the effects of non-reciprocity they have called the phenomenon in question "circuit asymmetry."

In examining the performance of a number of long-distance circuits, in terms of the number of commercial hours per day or days per month, they found that, in the cases where one terminal was in the northern and one in the southern hemisphere, a marked deterioration in circuit performance occurred during local summer. Since the time of local summer in these cases is displaced by six months as between the two opposite circuit terminals, this means that the performance varies in anti-phase at the two terminals over the year. Even if no other difference were present this leads to a differential in the circuit performance as between the "go" and "come" directions; in other words, to a seasonal asymmetry. (See accompanying diagram.) But, superimposed on this, there may be a consistently worse performance in one direction than in the other; i.e., a long-term asymmetry. Where both terminals were in similar latitudes in the northern hemisphere, where the seasons are coincident at the terminals, there was no evidence of seasonal asymmetry, though a component of long-term asymmetry might still be present.

These results are exactly what would be expected from a consideration of the likely signal/noise ratio, taking into consideration the local variations in atmospheric noise. This is, of course, much higher in summer than in winter, and varies geographically in a manner such that, generally speaking, its intensity is an inverse function of latitude. Thus, even with non-directional aerial systems such asymmetrical conditions would occur. But the communication systems in question used relatively sharply directional aerials, "beamed" in the direction of the distant terminal, and the authors have probed the matter further in view of this.

In considering the diurnal variations in circuit asymmetry, over several circuits where one terminal was in the United Kingdom and the others at places near or south of the equator, they found a marked tendency for the asymmetry to increase; i.e., circuit performance at the United Kingdom end to deteriorate, at a certain time GMT for each circuit, which time varied for the different circuits so as to become systematically later as the circuit direction varied from the east towards the west. This

* Research Dept., British Broadcasting Corporation.

was particularly marked in the northern summer. The time of this increase in circuit asymmetry was, in fact, found to be at approximately similar values of local time at the distant terminal; i.e., between about 1850 and 2020 Local Mean Time. The implication was that towards and after local sunset at some place within the main beam of the receiving aerial, in the direction of the distant terminal, there was a significant increase in the atmospheric noise, such that the signal/noise ratio at the United Kingdom end of the circuit sharply decreased, and that as the sunset line moved from east to west over the circuits so the circuit asymmetry increased at increasing values of GMT, according as the direction of the circuit became farther to the west.

Atmospheric noise should be regarded as being primarily a meteorological phenomenon, being due to the lightning strokes in thunderstorms. The conditions for the production of thunderstorms are intimately bound up with the heating of the air by conduction from the earth under the influence of the sun's rays. Thus peak thunderstorm activity occurs in the late afternoon and evening, and, when the ionospheric conditions for the transmission of the noise over a distance are taken into account, it appears that a directional receiving aerial would tend to pick up the highest level of noise from an area lying slightly west of the sunset line. This enabled the authors to locate approximately the position of the noise sources responsible for the deterioration in circuit performances at the United Kingdom end of the circuit, for each of the circuits being examined, and a scrutiny of the receiving operator's logs confirmed that there was an increase in the atmospherics at about the times expected.

Thus, it may be concluded, there is, at certain times of day, a deterioration in circuit performance over long-distance circuits in the direction in which reception is taking place in local summer, thus leading to a pronounced tendency for circuit asymmetry to occur. In addition, there may be long-term asymmetry, due to consistent differences in the local noise levels and, possibly, to other differences in conditions at the receiving terminals. Of the two effects of non-reciprocity and circuit asymmetry it would seem that the latter is responsible for the *major* differential effects observed in practice for transmission in opposite directions over a circuit, at least when the two terminals are located in widely different latitudes.

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BOOKS RECEIVED

Vacuum Tube Circuits and Transistors by L. A. Arguimbau. New edition of textbook dealing with the circuitry of radio communications, now including chapters on transistor devices and circuits by R. B. Adler. The treatment throughout is based on fundamental physical principles. Pp. 648 + IX; Figs. 612. Price 82s. Chapman and Hall, 37, Essex Street, London, W.C.2.

Quartz Crystals as Oscillators and Resonators by D. Fairweather, A.M.I.E.E. and R. C. Richards, Assoc.I.E.E. Monograph on the types of crystal cuts available and their practical applications in the control of frequency, with particular reference to preferred circuits and their design. Pp. 54; Figs. 52. Price 7s 6d. Marconi's Wireless Telegraph Co., Ltd., Chelmsford, Essex.

Proceedings of the Conference on Radio Interference Reduction (Chicago, December 1954). Subjects discussed include techniques for suppression in motor cars, aircraft and ships; design of screening; susceptibility of receivers to pulse interference; spurious radiation from transmitters; corona interference in aircraft; measurement techniques. Pp. 352 + V; Figs. 170. Price $6.00. Armour Research Foundation, Dept. E, 10 W. 35th Street, Chicago, Illinois.

Television Programming and Production by Richard Hubbell. Revised and enlarged third edition of a handbook on camera technique, staging and sound effects written primarily on the basis of American practice, with a chapter on British television programmes. Pp. 272; Figs. 18. Plates **117**. Price 32s. Chapman and Hall, 37, Essex Street, London, W.C.2.

Basic Electricity by P. B. Zbar and S. Schildkraut. Instruction manual for a series of laboratory experiments to familiarize radio technicians with measurements on simple d.c., a.c., and r.f. circuits. Pp. 84; Figs. 113. Price 13s. McGraw Hill Publishing Co., Ltd., 95, Farringdon Street, London, E.C.4.

Handbook of Basic Circuits by M. Mandl. Selection of 136 basic circuit elements, arranged in alphabetical order for easy reference, indicating their application in sound or television receivers and describing their purpose and function. Appendices give block diagrams of representative complete equipments. Pp. 365; Figs. 164. Price 52s 6d. The Macmillan Company, 10, South Audley Street, London, W.1.

Profitable Radio Troubleshooting by W. Marcus and A. Levy. American treatise on servicing from both the technical and business points of view. Pp. 330; Figs. 153. Price 34s. McGraw Hill Publishing Co., Ltd., 95, Farringdon Street, London, E.C.4.

Commercial Broadcasting in the British West Indies. Detailed account produced by Central Rediffusion Services, Ltd., of the organization and distribution of programmes in the main islands by medium-wave, v.h.f. and wire. Pp. 91; Figs. 31. Price 5s. Butterworth Scientific Publications, 88, Kingsway, London, W.C.2.

Dictionnaire Français-Anglais, by H. Piraux. Complementary volume to the English-French dictionary previously published, giving equivalent terms relating to electronic and electrotechnical subjects. Pp. 186. Price 960 Fr. Editions Eyrolles, 61, Boulevard St. Germain, Paris, 5.

RCA Transmitting Tubes. Manual of valve characteristics covering anode, ratings up to 4 kW, with an introduction on circuit design considerations and recommended operating conditions. Pp. 257. Price 12s. RCA (Gt. Britain), Ltd., Lincoln Way, Sunbury-on-Thames, Middlesex.

The Gated-Beam Valve

By

*LAWRENCE W. JOHNSON**

Its Use as Limiter and Discriminator for Frequency Modulation Reception

ADVANCES in the art of frequency modulation reception seem all too often to come about only as a result of advances in allied, higher-powered fields. Exceptions to this rule do exist—for example, the M.I.T. work on multi-path transmission[1,2]—but it is safe to say that if it were not for radar and television, the low-noise front ends and compact i.f. amplifiers used in modern f.m. receivers would not be available. It is the purpose of this paper to describe the 6BN6 gated-beam tube, a television development which bears out the original contention. To the designer of f.m. tuners and receivers it brings a very useful tool in improving performance or in lowering price, whichever objective may be the more important.

The 6BN6 was developed in the laboratories of the Zenith Radio Corporation, by a group led by Dr. Robert Adler, and was first put into production by the General Electric Company (U.S.). The basic ideas were not new, but Adler's work seems to have been the first to combine them all successfully. The prime purpose of the development appears to have been the simplification of the sound channel of television receivers. When the 6BN6 is so used it takes the place of the limiter, discriminator, and first audio stages, and at the same time eliminates the rather complicated phase discriminator or ratio detector transformer, substituting in its place a simple inductor resonant at the intermediate frequency[3,4]. The resulting f.m. detector does not meet the requirements set forth for an exceptionally high capture ratio[2], but its performance equals or surpasses that of the commonly encountered ratio detector or single-limiter/discriminator. In some high-quality f.m. tuners the 6BN6 is employed as a broad-band limiter only, and is followed by a separate broad-band detector to assure a good capture ratio.

Counter Discriminators

Understanding the operation of the 6BN6 is not difficult if one falls back upon previously explained phenomena and circuits. Roddam[5] and Scroggie[6] have done much to familiarize readers of this journal with low-frequency versions of the counter type of discriminator, which presents several intriguing advantages, but also imposes limitations on bandwidth because of the necessarily low intermediate frequency. The 6BN6 may be thought of as a way of utilizing the same general principle as that of the counter discriminator, at an almost arbitrarily high intermediate frequency. This last-mentioned property might seem to provide a large advantage over other counter-discriminator systems in that an excellent capture ratio would seem to be within reach. That this is not completely true will be discussed in detail later; envelope for envelope, however, the 6BN6 still provides several points of superiority over practical counter detectors.

The conventional counter detector utilizes the principles of pulse position modulation (p.p.m.); it is supposed, ideally, to put out one pulse for each cycle of the incoming frequency-modulated voltage. It is assumed that the output pulse will have a standard height, duration, and shape, regardless of the input frequency and amplitude. The resulting train of pulses, identical in all respects save spacing, can be passed through a low-pass filter, at the output of which will appear the desired audio signal representing the demodulated wave. Fig. 1 shows an f.m. wave and an idealized counter detector's action. It is only a simple step to consider instead a system where the "duty cycle" (ratio of pulse duration to the full repetition period) instead of pulse spacing is varied. This is the scheme which the 6BN6 detector employs. Current pulses are formed which have standard height, rise time, and fall time; they vary in both width and spacing, but the significant fact is that the duty cycle, nominally 25% with no modulation, is made to vary in accordance with the deviation of the instantaneous input frequency from the fixed intermediate frequency. As before, the current pulses are passed into a low-pass filter, which yields an output proportional to duty cycle, thus conveying the desired modulation intelligence.

Dual Control Grids

The details of the manner in which the 6BN6 accomplishes these functions are fairly straightforward. For the present let it suffice to say that the 6BN6 has two control grids, well-shielded from each other, both of which are capable of cutting off anode current, and whose dynamic ranges are both quite small. Thus an alternating voltage on either electrode of a few volts amplitude, peak-to-peak, will cause

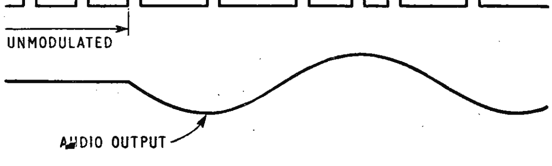

Fig. 1. Principle of the pulse counter detector.

*Hewlett Packard Company, Palo Alto, California.

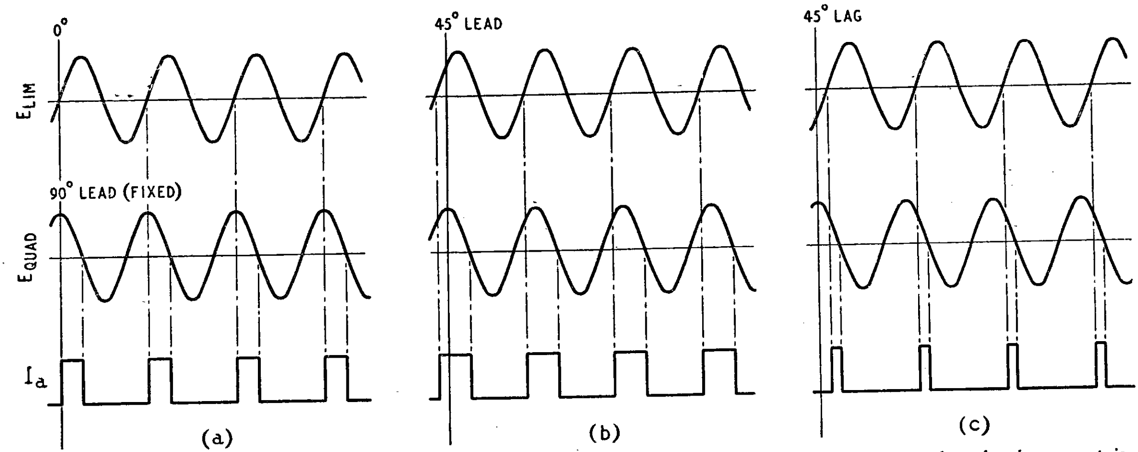

Fig. 2. Variation in pulse duty cycle for changes of phase between the limiter and quadrature grids. Anode current is assumed to flow only when both grids are positive.

pulses of anode current to flow as the electrode voltage is carried from cut-off to saturation and back. For reasons that will be clear later, the closer of the two grids to the cathode is called the limiter grid, and the other is called the quadrature grid.

Suppose now that an unmodulated signal is applied to the limiter grid, and that the same signal, advanced in phase by 90 degrees, is applied to the quadrature grid. (The reason for the name may now be growing apparent.) If the amplitudes of the two voltages are sufficient, either by itself would suffice to form pulses of anode current, and if one or the other were of zero amplitude, the other would cause the anode current duty cycle to be 50%. Fig. 2(a) shows how, with the application of voltages 90 degrees apart, the anode current duty cycle would be reduced to 25%. For simplicity, current is assumed to reach the anode only during the portion of the signal cycle when both grids are positive.

What happens if the phase of the voltage applied to the limiter grid is varied, while that of the voltage applied to the quadrature grid is kept steady as in the initial example? If the phase of the limiter grid voltage is advanced by 45 degrees, the anode current pulses will be as shown in Fig. 2(b); the duty cycle has been increased to 37½%. Alternatively, if the phase of the limiter grid voltage is retarded by 45 degrees, the anode current pulses will be as shown in Fig. 2(c); now the duty cycle has been decreased to 12½%. Bear in mind that Fig. 2 is for a voltage of constant frequency and unchanging phase applied to the quadrature grid, with variation only of the phase of the voltage applied to the limiter grid; these conditions are exactly what might be encountered in a phase detector. That is, such a circuit would provide a d.c. output that would vary in proportion to the phase difference between a variable-phase carrier-frequency input and a fixed-phase carrier-frequency reference input. The line between phase and frequency is a hazy one; if, for example, one speaks of a continuously changing phase, one may equally well speak of a frequency shift. Thus it is that phase detectors and frequency modulation detectors often have very similar circuits.

The 6BN6 phase detector can be used almost without change as a frequency modulation detector; it is necessary only to arrange somehow to supply an appropriate reference voltage to the quadrature grid. The signal to be detected will be applied to the limiter grid; a convenient result of the narrow dynamic range of the limiter grid is that amplitude modulation of the input signal will have little effect on the timing of the anode current switching.

Practical Circuit

Fig. 3 shows the circuit actually used in the 6BN6 f.m. detector. The representation is drawn in the fashion of a pentode; more physical detail will be given later. The limiter grid is that nearest the cathode, while an accelerator or screen grid is between the limiter and quadrature grids. The signal to be detected is connected to the limiter grid, a moderately-high-Q resonant circuit is connected to the quadrature grid, a typical screen grid voltage is applied to the accelerator, and to the anode are attached a load resistor, an integrating capacitor (to earth), and a coupling capacitor (to the audio amplifier). With this circuit configuration, consider the situation when a signal is applied of the same frequency (the intermediate frequency of the receiver)

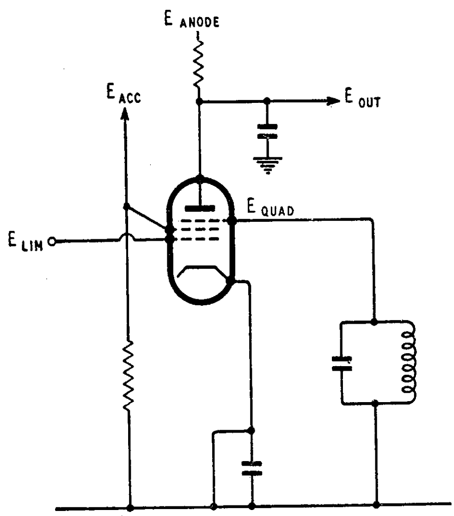

Fig. 3. Basic circuit of gated-beam limiter discriminator.

as that to which the coil in the quadrature grid circuit is tuned. Under these conditions there is space charge coupling to the quadrature grid circuit as a result of the pulses of current passed by the limiter grid. There results a current in the quadrature grid circuit whose frequency is that of the current pulses, and whose amplitude is broadly frequency-dependent. Thus there is produced a voltage from quadrature grid to earth at the input frequency, of amplitude sufficient to carry the quadrature grid considerably past the cut-off and saturation limits, so that the pulses of beam current produced by the limiter grid will be further modified before they become pulses of anode current. Just how they are modified is determined by the phase difference between the limiter and quadrature grid voltages. The quadrature grid circuit situation is analogous to that of a parallel resonant circuit fed through a small capacitive reactance; at resonance the voltage across the resonant circuit leads the current by 90 degrees, and at frequencies near resonance the lead angle is given by an approximation quite accurate for frequency deviations of 75 kc/s or less, and for quadrature inductor Qs of 35 or less. The approximation states that

$$\phi=\frac{\pi}{2}-2Q.\frac{\Delta f}{f_0}$$

where ϕ is the lead angle in radians, Q is the figure of merit of the quadrature coil, f_0 is the intermediate frequency to which the quadrature coil is tuned and Δf is the deviation of the input frequency from f_0.

Linearity

From this relation it is clear that the anode current duty cycle is 25% when the input frequency is equal to the intermediate frequency. And further, as the input frequency is varied, it is clear that the phase difference varies in a linear fashion, producing a linear variation in duty cycle of the anode current pulses, along the lines of what was described earlier for the 6BN6 phase detector; for a frequency above the intermediate frequency, the duty cycle is less than 25%, and for a frequency below the intermediate frequency, the duty cycle is greater than 25%. This fortunate situation has resulted from quadrature circuit phase changes resulting from forced oscillations excited therein by means of space charge coupling from the beam current.

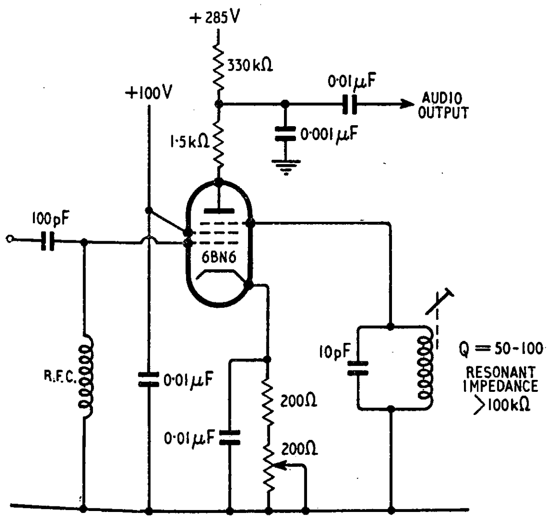

Fig. 4. Practical circuit with component values for the 6BN6 valve.

TABLE I

6BN6—Limiter-Discriminator Characteristics and Typical Operation

Input-signal centre frequency	10.7 Mc/s
Frequency deviation	±75 kc/s
Anode supply voltage	285
Anode voltage	122
Accelerator voltage	100
Cathode-bias resistor (variable)*	200 to 400 ohms
Anode load resistor	330,000 ohms
Anode linearity resistor	1500 ohms
Integrating capacitor	0.001 μF
Coupling capacitor	0.01 μF
Minimum signal voltage for limiting action (r.m.s.)†	2.0
Average d.c. anode current	0.49 mA
Accelerator current	9.8 mA
Input signal level for a.m. rejection adjustment*	2.0 volts
A.M. rejection at E_{sig} = 2.0 volts (r.m.s.)	20 dB
A.M. rejection at E_{sig} = 3.0 volts (r.m.s.)	29 dB
Total harmonic distortion	1.6 %
Peak audio output voltage	16.6

*The cathode resistor should be adjusted for maximum a.m. rejection in the output of the limiter discriminator stage at the specified signal level. a.m. rejection is measured with an applied signal containing 30% a.m. and 30% f.m.

†At signal levels above specified value, limiting is within ± 2 dB.

As before, the desired audio signal can be recovered by means of an integrator or low-pass filter. Appropriate choice of low-pass filter components can provide simultaneous de-emphasis, yielding further simplification of the circuit. The values shown in the detailed circuit of Fig. 4 are designed to compensate for the 75-microsecond pre-emphasis, standard in the U.S. Also shown in Fig. 4 is an additional linearity resistor between anode and integrating capacitor. This resistor, by permitting an appreciable component at carrier frequency to exist at the anode, modifies the phase and amplitude of the quadrature grid voltage by feedback through the quadrature-grid-to-anode capacitance in such a fashion as to improve linearity considerably. This resistor also has some effect on the amplitude of the output voltage, and on the a.m. rejection capabilities of the circuit, so that its value represents a compromise between conflicting requirements. Table 1 gives the characteristics and typical operation furnished in the manufacturer's technical data manual[7], from which the circuit of Fig. 4 was taken.

Simple Adjustment

Alignment of the circuit turns out to be admirably simple. The quadrature coil is tuned for maximum audio output, and the cathode resistance is adjusted for optimum a.m. rejection. Both these adjustments can be made without a signal generator; in fact the latter is very easily made when receiving a weak station in the presence of impulsive noise interference. It is important to note that symmetry of the tuning characteristic will be adversely affected unless anode current without signal equals anode current with an unmodulated signal. Thus the use of other supply voltages than those listed will require that the value of anode resistor be adjusted. It is desirable in addition that the accelerator be fed from a low impedance source.

A cross section of the 6BN6 electrode structure is shown in Fig. 5. Note that the limiter grid is almost completely enclosed by a structure at cathode potential, which in turn is almost completely surrounded by the accelerator. Note also that the anode and quadrature grid are almost completely enclosed in another structure at cathode potential. With such a structure it should not be surprising that the direct capacitance between quadrature grid and limiter grid is less than 0.004 pF. The limiting action of both grids is accomplished by means of carefully planned electron-optical conditions. Either grid will draw no more than 0.5 mA no matter how far positive it may be driven, and the box structure, combined with the sheet-beam resulting from careful electrode layout, yields a sharp cut-off characteristic. In fact, as long as the signal applied to the limiter grid is above about two volts r.m.s., the space current which passes out of the accelerator is carried rapidly from zero to the saturation value; consequently the name limiter grid is justified, for any larger amplitude of input voltage will only sharpen the transition from zero to the saturation value.

The Q of the quadrature coil can vary between fairly broad limits. On the one hand, it must not be too sharply tuned, or the amplitude of the quadrature voltage may drop off at large deviations, and the phase deviation may depart from linearity. On the other hand, it should not be too broad, since there is then danger of insufficient quadrature grid voltage as a result of the reduced quadrature coil voltage. As a practical matter to insure continuity of operation with valve replacement, the manufacturer recommends that a total of at least 10 pF of capacitance be used across the quadrature coil. Needless to say, careful shielding of the quadrature circuit is necessary, especially from the input circuit to the limiter grid. Broadening the quadrature coil tuning will aid in broadening the bandwidth of the 6BN6 detector, but it appears that the practical upper limit will still not permit its use in a design which calls for a two- or three-megacycle detector bandwidth. Nevertheless the circuit fits well the requirements of low cost receivers, since it will still provide a greater-than-normal bandwidth while providing a high output voltage, thus contributing to the simplicity and low cost of such a receiver while keeping quality reasonably high.

Use as Limiter

The characteristics of the limiter grid suggest that the 6BN6 can be profitably employed as a pure limiter. This is in fact the case. For use as a limiter the manufacturer suggests that the quadrature grid should be connected to the anode if the maximum amplitude of output voltage is desired, or to earth if limiting on the smallest possible input signal is desired. Particularly desirable in a limiter is the characteristic of the 6BN6 that results from its electron-optical design; limiting does not depend on flow of grid current, nor in any way on biases determined by signal levels. Thus there are no time constants associated with the limiting action, which cannot be said to be true of the familiar pentode limiter, or even of some diode limiters. Thus the 6BN6 provides improved immunity from impulse interference and from rapidly changing signal levels, in contrast to the pile-up effect characteristic of pentode limiters. These several advantages have led to the appearance of the 6BN6 as a limiter in several high-quality f.m. receivers. It may be that

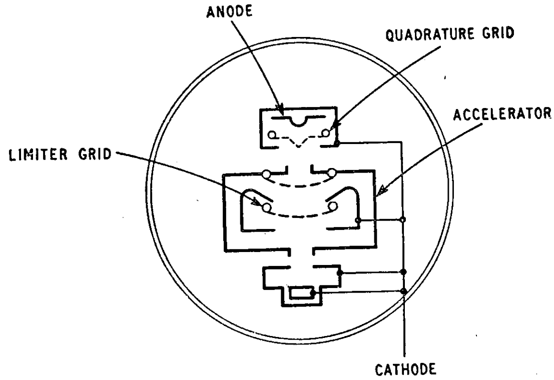

Fig. 5. Cross-section of electrode structure in the 6BN6 valve.

its failure to appear as a limiter-discriminator in inexpensive tuners is attributable to a stigma based on its television cost-cutting background. Such a reluctance is certainly not justified, since the 6BN6 when properly used can out-perform the presently popular ratio detectors and discriminators used in inexpensive equipment.

A detailed study of the gated-beam limiter at M.I.T.[8] bears out the conclusions stated above about the excellence of its properties. The study recommends separate control of the biases on limiter and quadrature grids for optimum adjustment of limiting characteristics. This appears to be desirable because of variations in characteristics from valve to valve. Cascaded 6BN6 limiters with earthed quadrature grids were used in the Cross-Paananen receiver developed at M.I.T.[9,10], and mentioned in an earlier article in this journal[2].

A recently announced R.C.A. development[11] seems to be very similar to the 6BN6 detector circuit described above. The circuitry is essentially identical, but the operation differs in that the detector is normally oscillating, and only for strong signals does the oscillation cease. For weak signals the action is along the lines of the locked-oscillator detector, developed and used some years ago[12]. There is no indication that the 6DT6, the special pentode developed for this circuit, possesses the electron-optical limiting characteristics of the 6BN6. It is possible that a marriage of the two schemes, combining the good features of both, would prove interesting. Presumably such an approach would involve modifying the 6BN6 circuit so that it would oscillate for low values of input signal.

D.C. Component

There is a characteristic of the 6BN6 detector that may be considered by some to be a disadvantage. There is present at the anode a d.c. voltage which varies in the fashion required for control of an automatic frequency control circuit, except for the fact that the voltage level for centred tuning is not zero but is instead of the order of 100 volts. This makes difficult, but not impossible, the job of designing an a.f.c. circuit, the need for which might better be counteracted by devoting care to the design of the local oscillator.

Tuning meters can easily be used with the 6BN6 circuit; the limiter grid current, never greater than one half milliampere, is a wonderfully sensitive aid in tuning weak stations, while for strong stations the grid current of the preceding intermediate frequency amplifier stage—which would be the logical source of automatic gain control voltage in a 6BN6 receiver—provides a sensitive indicator. The provision of a zero-centre on-channel indication falls in the same category as providing a.f.c., however.

Modification of existing equipment to employ the 6BN6 as a limiter-detector is quite practical, and in most cases will yield an improvement.

Existing limiters can be converted to additional intermediate frequency amplifier stages by appropriate adjustments of their operating conditions, and the discriminator or ratio detector transformer can often be converted into a driver transformer for the 6BN6 limiter grid. Room for a shielded quadrature coil must be located. The d.c. resistance in the 6BN6 limiter grid circuit should be kept under 200 ohms, lest the flow of grid current upset bias conditions. The results of such a modification will generally be as follows: sensitivity will be increased, noise rejection will be improved, alignment will be easier, and tuning will be easier. This last feature is perhaps as welcome as any of the others. It results from the fact that the broader-than-usual bandwidth of the 6BN6 detector effectively eliminates the three-point detection usually encountered, substituting instead a broad region of smooth tuning with noisy regions on each side which result from slope detection in the intermediate frequency amplifier and consequently present a highly amplitude-modulated signal to the limiter grid. This tuning characteristic makes it convenient to design an inter-station squelch circuit activated by the super-audible components present in the inter-station noise.

In closing it might be noted that many applications other than those mentioned have been found for the 6BN6. It is useful as a clipper, square-wave generator, frequency multiplier, gated amplifier, coincidence circuit, slicer, or multivibrator. And finally, it seems to be the only tube which can be self-biased to anode-current cut-off.

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Modernizing T.R.F. Television Receivers

By P. F. CUNDY, A.M.I.E.E.

FOLLOWING the article by G. J. Conway in the November, 1956, issue, it is worth while considering another method of converting Channel-I "straight" vision receivers to Crystal Palace single-sideband transmissions, and at the same time introducing Band III reception.

In simple terms this method is to change all sound channel circuits and traps from 41.5 Mc/s to 38.15 Mc/s, the vision circuits from 45-48 Mc/s to 34.65-37.65 Mc/s, and to add a multi-channel tuner in front. The previous signal-frequency sound and vision stages are thus converted to the standard recommended British intermediate frequencies, and any tuner with the "standard" i.f. output will do.

This treatment can be applied to "straight" sets in each of the following circumstances:—

(1) Upper-sideband types.

(2) Double-sideband types.

(3) Lower-sideband types when a simply added Band-III converter cannot be used because of 45 Mc/s re-radiation from the receiver or because of direct 45 Mc/s pick-up.

In most cases the existing trimming arrangements on the sound channel cater for the change from 41.5 Mc/s to 38.15 Mc/s (which is about 8%) and this is also true of the sound traps. Sets of type 2 and 3 would have had sufficient sound attenuation in their existing trap circuits to make alterations (other than tuning) unnecessary.

In general, type 1 receivers will need at least one additional sound trap. This can be made and fitted in exactly the same manner as described by Conway, but, of course, designed to resonate at 38.15 Mc/s.

With the vision circuits, the change in frequency required is up to 22% and this is usually well outside the range of the existing trimming facilities. The simplest way to lower the frequency of these circuits is by additional capacitance. A value of 6.8 pF is the best starting point and capacitors of this value should be connected from anode to earth and from grid to earth of each valve handling vision-frequency signals. Care must be taken that these capacitors and the leads to them are positioned so that the anode-to-grid capacitances of the amplifying valves are not augmented by excessive external feedback, or stability will suffer.

During alignment it may turn out that the 6.8-pF capacitor is either too large or too small. In this case it should be changed for a 4.7-pF or a 10-pF capacitor, but 6.8 pF will be right for at least 75% of the requirements.

The added capacitance increases the selectivity and this could be troublesome. It is not worth while, however, changing damping resistors where they exist and are 10 kΩ or less. To any circuits which in the original condition were not provided with damping resistors, values of 15 kΩ or 22 kΩ may be added.

On the question of alignment procedure it is impossible to give any specific advice. If carried out by somebody who has an instinct for this kind of thing it is not difficult, but in the absence of an oscilloscope and sweep generator it can be tedious. A good starting point is to align all circuits on 34.56 Mc/s and then raise the frequency of two-thirds of them slowly, leaving one-third at about 36.15 Mc/s and pushing the remaining one-third as near 37.65 Mc/s as possible without running into sound-on-vision. It should be borne in mind that the sound rejectors may require some re-adjustment in the process.

Acceptable performance should always be achievable, with bandwidths of 2 Mc/s in all cases and 2.5 Mc/s quite often. Users of the well-known Pye 45 Mc/s strip will find the conversion satisfactory, and because of the large number of tuned circuits it is possible to avoid the use of sound traps. Responses 3 dB down at 37 Mc/s, 15 dB down at 37.5 Mc/s and 30 dB down at sound carrier frequency can be achieved by tuning adjustment alone.

Gain lost in adding capacitors and damping resistors to amplifying stages will be more than made up by the tuner. Since few of the receivers will have provision for any form of a.g.c., adjustment of contrast control on changing channels will usually be necessary.

Good results have been obtained with the conversion of several receivers, both commercially-made and home-constructed. The Cyldon "Teletuner" has been used successfully, and also the G.E.C. type BT205 adaptor and a home-built tuner.

Transatlantic Television

BRIEF mention was made in last month's "World of Wireless" of the successful reception of B.B.C. television transmissions in the United States. Since then, further details of the reception arrangements have been given to *Wireless World* by Dr. H. R. L. Lamont, European technical representative of the Radio Corporation of America.

The main receiving aerial is a horizontally polarized rhombic (mounted on 50-ft wooden poles) with an overall length of 329ft. The side angles are 142° and the side lengths 173ft. The aerial is designed for our Channel 1, with the main lobe 7° above the horizon in the great circle azimuth of London. The far end is terminated in 800 ohms with the near end working into a 50-ft length of tapered impedance matching transformer. This feeds through approximately 100-ft of 300-ohm balanced line to the receiving equipment.

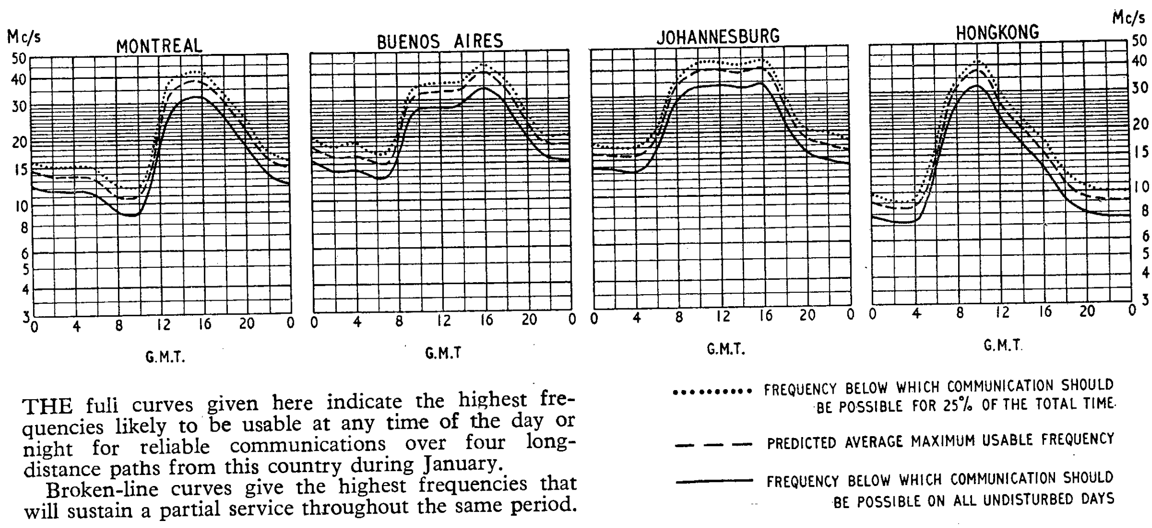
From the transmission line a 300- to 75-ohm balun, having less than 1 dB loss, a standing-wave ratio of less than 1 : 1.2 and a balanced to unbalanced ratio greater than 18 dB, is used. The pre-amplifier has a noise factor of 5 dB or less and a gain of approximately 25 dB. A network designed to reduce interference from strong off-channel stations is in the circuit after the pre-amplifier. Thereafter, the signal is fed to two Ekco T283 receivers. Two receivers are used because, with weak signals and intereference, optimum sound tuning does not always correspond to optimum picture tuning. Both receivers have been equipped with cathode-follower output systems, vision being taken from the second detector and sound from the loudspeaker speech coil circuit. The vision signal is then fed to a microwave relay system for transmission to the NBC Laboratory in New York, a distance of 70 miles from the receiving station at Riverhead, Long Island. Sound is conveyed by line.

In New York another Ekco receiver with an additional amplifier having a gain of approximately 10 to 1 is installed. Output from the amplifier is d.c.-restored by means of a diode where it is applied to the regular vision amplifier within the receiver. The received picture is then re-televised by a Vidicon camera chain operating from an RCA sync generator. The camera utilizes a 25-mm, f1.4 lens, and with this lens is capable of 600-line horizontal resolution.

Although recognizable signals have been received there has been considerable interference and multipath effects.

SHORT-WAVE CONDITIONS

Prediction for January



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 January.

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

LETTERS TO THE EDITOR

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

Is Distortion Unpleasant?

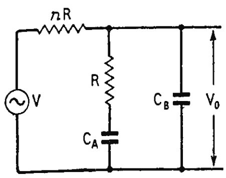
AS A. J. Hickman points out (December, 1956, issue), one can get used to anything: vibrato, dominant seventh chords, even deliberately mistuned "jazz" pianos, are sought after and give pleasure if not overworked.

The point is that all these effects are under the control of the musician, but the products of non-linearity are not.

Hindhead. HENRY MORGAN.

Disc Replay Equalizers

THE article by J. D. Smith on "Disc Recording Characteristics" in the November 1956 issue gives incorrect formulæ for the components of the combined network in Fig. 3. It can be shown that the correct formulæ should be as follows:—

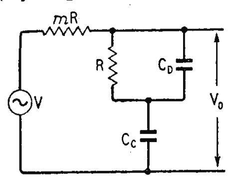


$$n=\left(t_1+t_3-t_2-\frac{t_1t_3}{t_3}\right)\frac{1}{t_2}$$

$$RC_A=t_2$$

$$RC_B=\frac{t_1\,t_3}{t_1+t_3-t_2-\dfrac{t_1t_3}{t_2}}$$

Another network which will give an identical frequency response curve is:—



$$m=\frac{t_1+t_3-t_2}{t_2-\dfrac{t_1\,t_3}{t_1+t_3-t_2}}$$

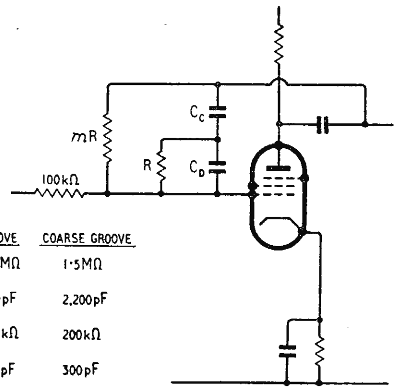
$$RC_C=t_2-\frac{t_1\,t_3}{t_1+t_3-t_2}$$

$$RC_D=\frac{t_1\,t_3}{t_1+t_3-t_2}$$

The error in Mr. Smith's formulæ may explain why his feedback circuit shown in Fig. 4 does not appear to conform to the combined network diagram.

It can be easily demonstrated that the frequency response V_0/V of the combined networks above is exactly the same as the variation with frequency of the impedance seen looking back into the output terminals of the network, so that these networks can be used directly in the feedback loop of an amplifier to get the desired replay characteristic. A third network is also available giving the same impedance variation.

A practical circuit would be:—



FINE GROOVE	COARSE GROOVE
mR = 3·3MΩ	1·5MΩ
C_C = 860pF	2,200pF
R = 270kΩ	200kΩ
C_D = 300pF	300pF

If the gain of the valve is not enough to prevent the bass response from flattening off due to the feedback becoming inoperative, then the value of *m*R may be increased or even omitted.

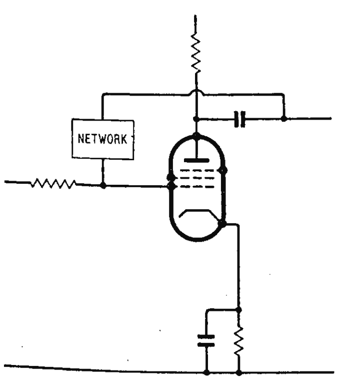
E.M.I. Studios, London, N.W.8. W. H. LIVY.

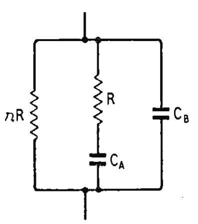
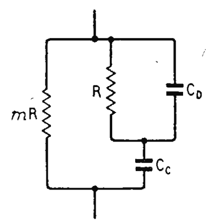
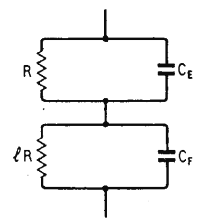
The Author Replies:

YOUR correspondent is quite right in taking me to task for misquoting the formulæ in Fig. 3. It will be noted that the expressions I gave are in fact approximations to the correct ones, since that for n may be rewritten as $n=\left(\frac{t_3-t_2}{t_2}\right)\left(1-\frac{t_1}{t_2}\right)$ which reduces to $\frac{t_3-t_2}{t_2}$, as given, when $t_1 \ll t_2$. In either case $RC_B=\frac{t_1t_3}{nt_2}$. Since Fig. 3. is intended to illustrate formal networks, I must apologize for quoting the approximate formulæ.

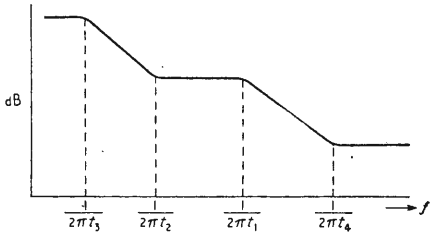
The approximation is valid when pre-emphasis is applied sparingly, as has been the practice in the past but which is scarcely true with the B.S.S. characteristics: the approximation is fair for the coarse groove case but somewhat gross for fine groove. The major inaccuracy is in the limitation of bass boost and does not exceed 2 dB, which for many purposes is sufficiently accurate.

The circuit of Fig. 4 of my article is not derived



		
$n=\left(t_1+t_3-t_2-\frac{t_1t_3}{t_2}\right)\frac{1}{t_2}$	$m=\frac{t_1+t_3-t_2}{t_2-\frac{t_1\,t_3}{t_1+t_3-t_2}}$	$\ell=\frac{t_3-t_2}{t_2-t_1}$
$RC_A=t_2$	$RC_C=t_2-\frac{t_1\,t_3}{t_1+t_3-t_2}$	$RC_E=t_1$
$RC_B=\frac{t_1t_2}{t_1+t_3-t_2-\frac{t_1t_3}{t_2}}$	$RC_D=\frac{t_1\,t_3}{t_1+t_3-t_2}$	$RC_F=\frac{t_3(t_2-t_1)}{t_3-t_2}$

directly from this combined network. Only two of the required time constants, t_1 and t_2, are included in the feedback network itself; the third appears by virtue of the finite gain of the valve which limits the bass boost. (If a circuit is to be used for equalizing several characteristics, some of which require less boost, this can be reduced by means of R_5.) There is a fourth time constant, t_4, due to the fact that the h.f. cut does not continue indefinitely. Hence, the overall response is of the form:—



In practice, this highest time constant is not observed since it occurs beyond the pass-band of the amplifier. The conditions giving the three plateau regions were shown in Fig. 5. It is clear that the design of the equalizer involves a knowledge of the gain of the stage and even then is not quite straightforward because the feedback network provides frequency-dependent loading on the anode circuit, so modifying the response in a manner which tends to increase both the bass boost and treble cut and should be allowed for (most readily by experiment).

Note that under the bass boost condition the stage is working without feedback so that the maximum mid-band gain is realized. Against this it must be admitted that the limiting boost is dependent on valve parameters and therefore liable to change with ageing, etc.

The two practical circuits cannot be directly compared as they fulfil different operational requirements. The one given by your correspondent employs more feedback and hence gives equalization accurately controlled by the network elements, but at the expense of overall gain. In many instances, greater gain is required and this is achieved by raising the network impedance until the bass boost is limited by the available valve gain and not by the network itself. Under these conditions it is often convenient to include redundant resistors in order to avoid the use of inconveniently large values and the circuit may then take a form similar to that which I gave (which is in fact a derivative of the third network given in Mr. Livy's letter).

Watford. J. D. SMITH.

Scale Distortion Again

"M. G. L." ends his review of a high-fidelity test record (December issue) by saying of loudness controls that they try "to reproduce an orchestra as it would be heard a long way away with the frequency balance as it would be audible much closer; and this cannot possibly lead to natural results."

The problem of scale distortion (loss in the ear of bass and treble at loudness levels less than natural) cannot be solved by ignoring it. The Fletcher and Munson curves show the loss of bass to approach 14 dB per octave at very low levels, and compensation is essential to hear the bass at all. Reproduction of an orchestra at full volume cannot be tolerated in ordinary rooms, and would be unnatural anyway. Reduction by ordinary (uncompensated) volume-control in effect removes the orchestra "a long way away" with loss of bass and treble, and makes the music thin, monotonous and tiring to listen to.

Reduction by compensated volume—so-called loudness—control effectively leaves the orchestra at its proper distance, but playing quieter (or with fewer members, if you will) *as would be expected* within the confines of an ordinary listening room, and therefore IS more natural.

Absolute fidelity in the home cannot be hoped for, due to the many well-known causes, but compensation for scale distortion is a valuable aid to the illusion of naturalness and the pleasure of listening—the real aim.

Walsall, Staffs. STANLEY MAY.

The Reviewer Replies:

I CANNOT agree with Stanley May's statement that "reproduction of an orchestra at full volume cannot be tolerated in ordinary rooms and would be unnatural anyway." The aim of correct reproduction is surely to produce in the ear the same sound pressures as would be produced in the ear in the concert hall. Subject to the usual distortions this can be achieved, and in the opinion of many people, including myself, leads to the most natural results. Many of us who share a belief in this standard think that music is often reproduced too loud by "hi-fi" addicts.

If an orchestra were to play quietly or with fewer members in the concert hall, owing to the scale distortion Mr. May mentions, the frequency balance heard would be different from that of a normal orchestra. Thus, even if for some reason we wish to reproduce our music as it would be played by such a smaller orchestra at the same distance as usual, it would be unnatural to compensate in the living room for a change which would remain uncompensated in the concert hall.

It is, however, possible that reproduction sounding like an orchestra which is the wrong size and has an incorrect frequency balance may be preferable to reproduction sounding like an orchestra of correct size and balance which is too far away. If we are restricted to these alternatives there may be some justification for Mr. May's use of a "loudness" control, but neither of these alternatives attempts to provide the correct reproduction that can to a large extent be achieved.

M. G. L.

The UL Circuit

I NOTED Grant's application (September, 1956, issue) of the UL circuit to single-sided pentodes with some interest. My company suggested this to a magazine editor here in the U.S. and he turned down the suggestion with the argument that it would not pay commercially since there is a patent licence problem.

A tap is required on a small and low-cost output transformer, and an engineer at one of the transformer companies was of the opinion that the tap cost would exceed that of an RC network for a conventional inverse feedback loop. Hence the UL circuit for a single-sided pentode doesn't seem to appear commercially attractive. However, in my opinion, it should work out better than an RC loop since there should be less trouble with poor "phase bandwidth" produced by a cheap output transformer.

TED POWELL.

Great Neck, L.I., U.S.A.

Audio Demonstrations

THE letters from C. Streatfield and H. Glover published in your October issue criticize the Radio Show demonstrations of sound-reproducing equipment and, in particular, the choice of programme material.

Perhaps the manufacturer who has the listener's ear for only a few minutes can be forgiven for trying to produce impressive rather than natural sounds. But if a test of naturalness is required, I, personally, remain convinced that speech is the best material. When well reproduced at the correct volume level the illusion of reality is, to me at least, greater than with other sounds well reproduced. But equipment which produces impressive bangs, crashes and tinkles doesn't necessarily seem to reproduce speech naturally.

London, N.W.7. W. J. CLUFF.

High-Quality Sound Broadcasting

By
G. H. RUSSELL
Assoc.Brit.I.R.E.

THE USE AND MISUSE OF V.H.F.

THE main justification for v.h.f. sound broadcasting is the poor reception conditions in the lower frequency bands. At the same time, it offers an unprecedented opportunity for giving sound broadcasting a new lease of life. This can be done only, of course, by taking full advantage of the potentialities of v.h.f. and in particular the wide audio frequency range that it makes possible.

In this context it is illuminating to compare the following separate statements taken from a new report* on v.h.f. sound broadcasting in Europe.

> "The programme input throughout is designed for a frequency band of from 30 to 15,000 c/s with all corresponding requirements of quality."

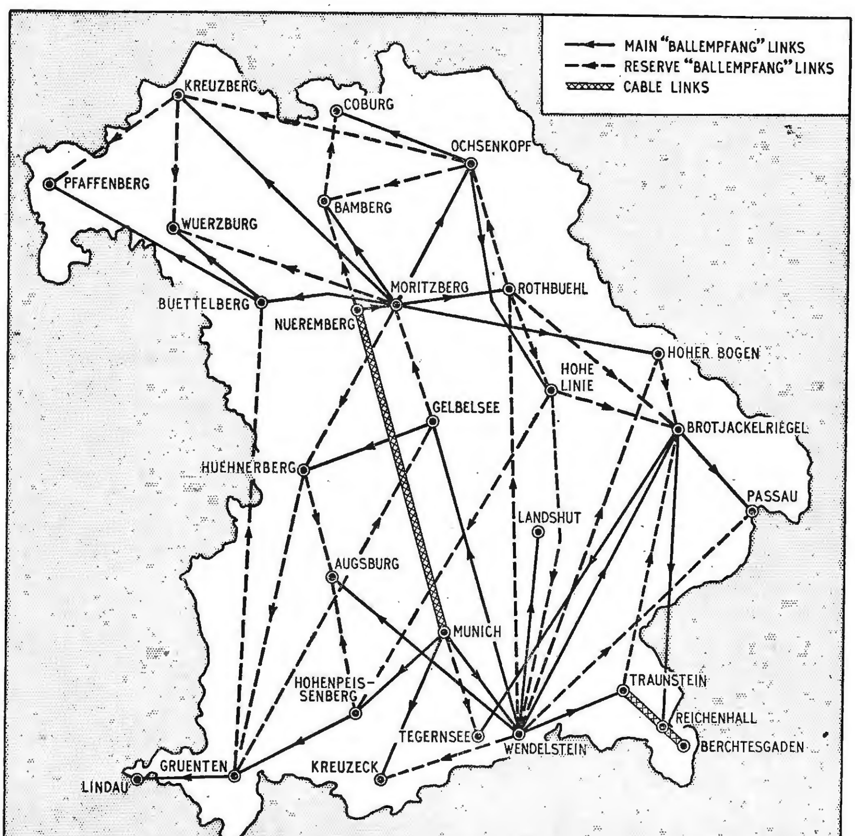
> "Nor will any changes be made in the line network; most of the lines at present rented . . . transmit frequencies up to about 8,000 c/s, and the cost of increasing this bandwidth (except in the case of short lines to local transmitting stations) would be prohibitive."

The first comes from the German contribution and is representative of the attitude of all but one of the European broadcasting authorities who have launched v.h.f. broadcasting schemes. Even a small country like Austria is busy improving the studio equipment to extend it to 15 kc/s. The second quotation, one regrets to say, is from the B.B.C. contribution.

The attitude of the B.B.C. to this question of the upper audio frequency limit is incomprehensible. If they had said that a restriction to 8,000 c/s was an unfortunate temporary limitation and efforts to increase this limit substantially would be made as soon as possible, it would have been understandable. Have the possibilities of unattended microwave links been examined? And has the question of direct re-broadcasting, which can be implemented at the cost of one aerial and one receiver per transmitter, been considered?

This system of direct re-broadcasting is being used extensively in Western Germany where it is known as *Ballempfang*. Indeed, it is also used by the British Forces' Network in that country.† The basis of the system is that signals from the originating station are received at the site of the nearest transmitter(s) where the demodulated signal is used to modulate the transmitter. Alternatively, the signal need not be demodulated but merely frequency transposed and re-radiated; this is called *Umsetzer*. It is self-evident that the cost of such a system will be only a fraction of that incurred by microwave or

* "The Present Position and Prospectives of V.H.F. Sound Broadcasting in Europe," Document Tech. 3068/E, published by the European Broadcasting Union.
† See *Wireless World*, February 1956.



Except for the links between the studios at Munich and Nueremberg, and between three stations in the south-eastern "peninsular" the whole v.h.f. network of 28 stations in the area covered by Bayerischer Rundfunk operates on the system of direct re-broadcasting.

cable links. The quality of the service rests upon that of the receiver at each station and the Germans claim that, with the receivers used, it is impossible to detect any degradation in quality even after six successive transmissions and re-transmissions.

One of the most complicated of these networks is that used by the Bavarian broadcasting authority and this is shown in the illustration. It is obvious that there are limits to the use of this system where a number of networks are used over a wide area involving many transmitters. Under these conditions one could conceivably arrive at the position where interference from another network could become a problem. In fact, this position has already arisen in Germany and, in future, cable links will be resorted to as the networks expand. Even so, all the cable links between transmitting stations and the extensions to the studio centres will eventually be able to transmit frequencies up to 10-11.2 kc/s.

Why Not in This Country?

It is realized that with its present network of v.h.f. stations it would be impossible for the B.B.C. to employ *Ballempfang*. However, the ultimate aim is for about 30 stations to cover the country with a three-programme service, and it would be encouraging to know that the B.B.C.'s intention was to use direct re-broadcasting and/or radio links to give us the kind of reproduction of which v.h.f. is capable. High-quality transmission might re-create public interest in sound broadcasting and stop the rot to television.

In Italy v.h.f. broadcasting is spreading fast,* but for a rather back-handed reason. Like our own B.B.C., the Italian authorities decided to place the v.h.f. sound and television transmitters on the same sites. Initially, it was proposed to proceed at a fairly leisurely pace determined by the rate at which a co-axial cable network could be laid. However, the public demand for television proved so impatient that it was decided to abandon the coaxial link in favour of microwave radio links. This enabled the authorities to bring into service simultaneously all the television transmitters initially projected and, in addition, the service has been extended to 83% of the population instead of the 54% originally planned.

In order to bring the v.h.f. sound broadcasting service into operation equally quickly, direct re-broadcast links are used in all but a few cases where microwave links are again resorted to. It is interesting to note the operational system evolved on the various transmitting sites. These sites are divided into three categories: main, secondary and satellites, of which there are 19, 16 and 48, respectively. This classification has nothing to do with the importance of the stations but with staffing. Thus, the main stations are fully and continuously manned; the secondary stations have a permanent caretaker with a team of engineers in attendance for short periods; and the satellites, which are automatically switched on and off, have no permanent staff. There is a lovable Latin touch to the monitoring system adopted for the satellite stations. A local big-wig in the nearest town, such as the policeman or postman, is appointed to this task. If the transmission should fail, he can bring in a reserve transmitter by remote control, after which it is his duty to telephone a report to the nearest main station.

While on the subject of radio links, it is notable that Denmark is considering the possibility of combining both sound and television links with those for the multi-channel telephone circuits. This would enable common power supplies to be used with a consequent saving in cost.

* Italy now has 102 transmitters in service.

Comparative Costs

In the E.B.U. Report a number of countries have given details of actual or probable costs of implementing v.h.f. networks. These are not of general interest except in the case of Sweden where an interesting cost comparison is made between v.h.f. transmission and wire distribution. Three proposals are put forward:

(a) A national f.m. network reinforced by wire distribution where reception is poor;

(b) National wire distribution; and

(c) F.M. transmitters for densely populated areas with wire distribution elsewhere.

The estimated cost for each of these schemes is £56M, £81M, and £52M, respectively. There does not seem to be much to choose between them. However, when the cost to the listener in new receivers or connecting cords for wire distribution is added, the picture becomes very different. This adds a further £115M, £8M and £95M, respectively. In spite of the economic factors, the Swedes have decided to adopt proposal (c), mainly on the grounds that radio distribution would enable a second programme to be brought to the densely populated areas much sooner than if wire distribution only was used.

Without wishing to resurrect the now very dead f.m. versus a.m. controversy, it is illuminating to compare the Swedish and British approaches to alternative systems. The figures presented to our Television Advisory Committee dealt with the capital cost of erecting and maintaining the transmitters only and left out the cost to the listener entirely. As can be seen from the Swedish figures, this cost can represent a substantial charge on the national income. It is to be hoped that on any future similar occasions which may arise this important factor will not again be omitted.

Before leaving the subject of wire broadcasting, it should be mentioned that no reference is made to it in the Swiss contribution despite the fact that Switzerland already has a first-rate network. Nevertheless, a network of f.m. transmitters is to be erected.

Because of the complex network of v.h.f. transmitters in Western Germany, v.h.f. portables and v.h.f. car radio have become popular. A further interesting development in Germany is the marketing by several firms of receivers that are able to receive television sound in addition to Band II transmissions. The purpose underlying this is that the addition of a simple vision-only receiver converts it into a combined sound and television receiver. It should, of course, be noted that the German television system uses f.m. sound and, furthermore, that v.h.f. sound broadcasting came before television in Germany.

A final note with a dreadful warning from Germany. The use of a 10.7-Mc/s intermediate frequency with poorly protected oscillators has resulted in "a critical situation so far as the final development of the v.h.f. network is concerned." There appear to be four million such receivers in use in Western Germany. No further comment is necessary.

Cascode Characteristics

GRAPHICAL METHOD OF CONSTRUCTION

By ***W. GRANT,*** **B.Sc.**

THE derivation of cascode characteristics by the use of the mathematical formulæ is a useful method of estimating the working parameters rapidly. It can, however, be misleading and a graphical approach presents a clearer picture and may lead to a better appreciation of the cascode mode of operation.

The static I_a/V_a curves of "single" valves are drawn with V_a and V_g stated relative to the cathode. The static curves of valves in the cascode connection are likewise stated relative to the cathode of the lower section. Fig. 1(a) shows the connection of two triodes in cascode indicating the voltages to which reference will later be made and the currents which do or may flow. Since the purpose is to derive the static characteristics no anode load is shown. Fig. 1(b) shows the d.c. voltage vectors for the general case.

In straight cascode operation V_{gc} is fixed and for the purpose of measuring the static curves V_{g1} may be fixed at each of several values while V_{ac} is varied in steps over the working range at each fixed value of V_{g1}, or *vice versa*. The curves of Figs. 5(b) and (6b) were measured using the first of these alternatives.

Figs. 2(a) and 2(b) show the I_a/V_a curves of two triodes. Fig. 2(a) will be considered to represent the lower section and Fig. 2(b) the upper section of a cascode pair of which the I_a/V_a curves are displayed in Fig. 3 and are derived as follows.

It will be seen from Fig. 1 that

$$V_{a1} = V_{k2} = V_{gc} - V_{g2} \quad (1)$$

and $$V_{a2} = V_{ac} - V_{k2} = V_{ac} - V_{gc} + V_{g2} \quad (2)$$

Equation (1) defines the constancy of V_{a1} and V_{k2}

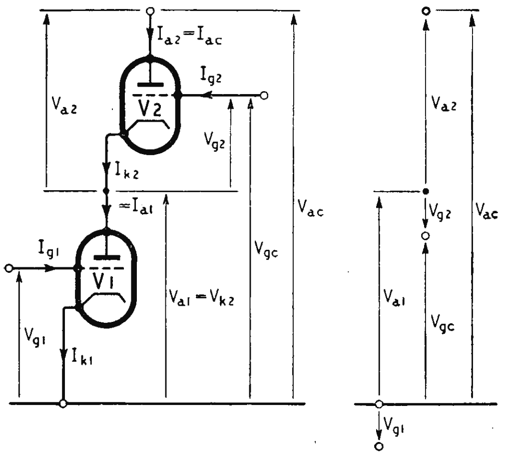


Fig. 1. (a) Cascode arrangement with voltage and current symbols used in the text. (b) Voltage vectors.

(the origin of the I_a/V_a curves of the upper section) for any constant value of V_{g2}. These two deductions from equation (1) make the graphical determination of cascode characteristics rapid and simple. The routine is tabulated below. The "something over" and "somewhat" become self-evident as the tabulation proceeds.

(1) Set out the I_a axis to a value equal to I_{a1} at V_{a1} equal to the proposed V_{gc} and something over, and the V_a axis to the supply voltage available, say 500 V.

(2) Erect the I_{a1}/V_{a1} curves (marking them lightly) for all relevant values of V_{g1} up to a value of V_{a1} somewhat exceeding V_{gc}.

(3) Since $V_{k2} = V_{gc}$ when V_{g2} = zero, erect the I_{a2}/V_{a2} curve for V_{g2} = zero taking V_{gc} as the origin of the curve.

(4) Mark off on the curve of step (3) the currents

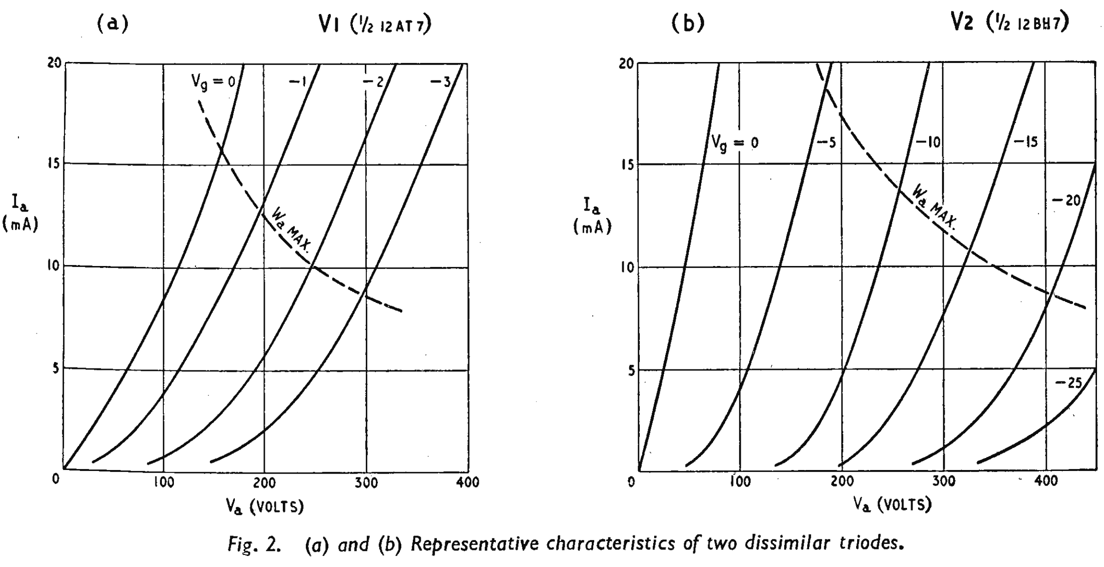


Fig. 2. (a) and (b) Representative characteristics of two dissimilar triodes.

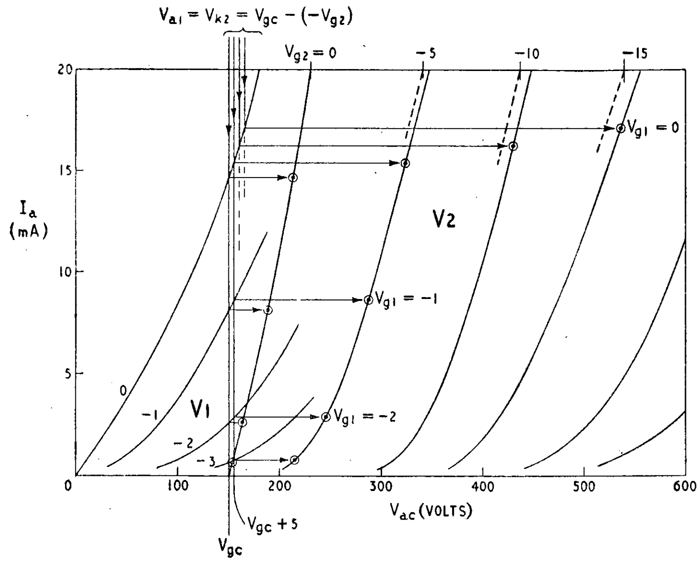
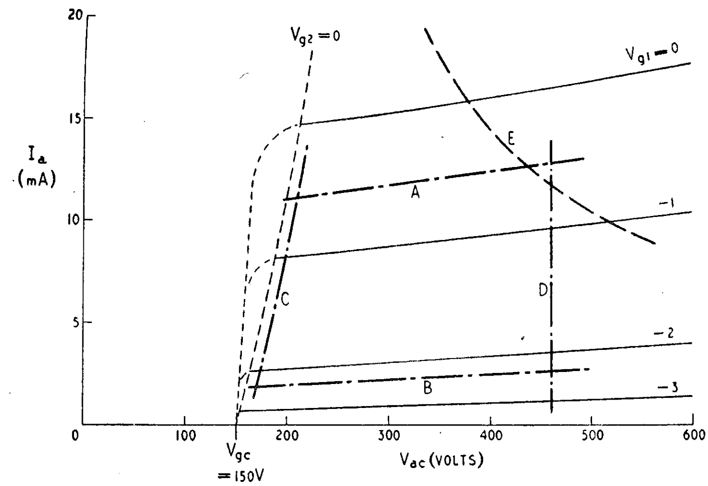


Fig. 3. Construction of cascode characteristics. Note that the curves of V1 are the same as in Fig. 2 (a), but that the origins of the V2 curves are successively displaced to the right by increments equal to the bias V_{g2}.



I_{a1} at $V_{a1} = V_{gc}$ for V_{g1} = zero, −1, −2 volts, etc.

(5) Choose a convenient value of V_{g2}, say −5 volts, and erect the I_{a2}/V_{a2} curve for $V_{g2} = -5$ taking $(V_{gc} + 5)$ as the origin.

(6) Mark off on the curve of step (5) the currents I_{a1} at $V_{a1} = (V_{gc} + 5)$ for V_{g1} = zero, −1, −2, etc. Steps (5) and (6) are to be repeated for larger values of V_{g2}, making the appropriate adjustments in the origins of the I_{a2}/V_{a2} curves, until the defining points are plotted as far as desired or the data allows.

(7) Join up all points corresponding to V_{g1} = zero, those corresponding to $V_{g1} = -1$, and so on.

Carrying the argument to the left of the curve V_{g2} = zero (step 3) it is seen that V_{g2} becomes positive and I_{a2} becomes less than I_{a1} by I_{g2}. Given the I_a/V_a data in the V_g positive region and also the I_g/V_g data for the upper section, the curves may be completed. Such data is published for very few valves so all that can be said is that I_{a2} falls off in some unknown fashion. This is seldom of importance since the area is valueless for linear amplification.

The working boundaries are marked on Fig. 4: they are:—

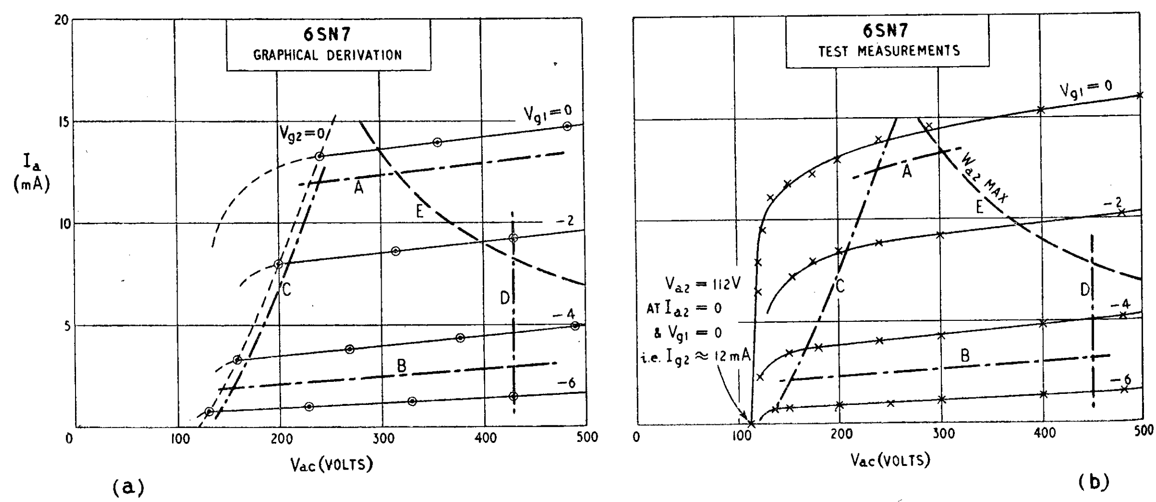
A, the onset of grid current, I_{g1}, in the lower section. This is a strict limit if the grid is returned to chassis through a resistor but may, of course, be relaxed if the return is through a coil of negligible resistance.

B, the limit of linearity of V_{g1}. This is variable and depends on the degree of distortion which can be tolerated.

C, the onset of grid current, I_{g2}, in the upper section. This is a limit to be respected as $I_{a2} = I_{a1} - I_{g2}$.

Left: Fig. 4. Complete curves developed by the method of Fig. 3 with the addition of working boundaries for linear operation.

Below: Fig. 5. Characteristics of a 6SN7 cascode stage; (a) graphical construction (b) measured.



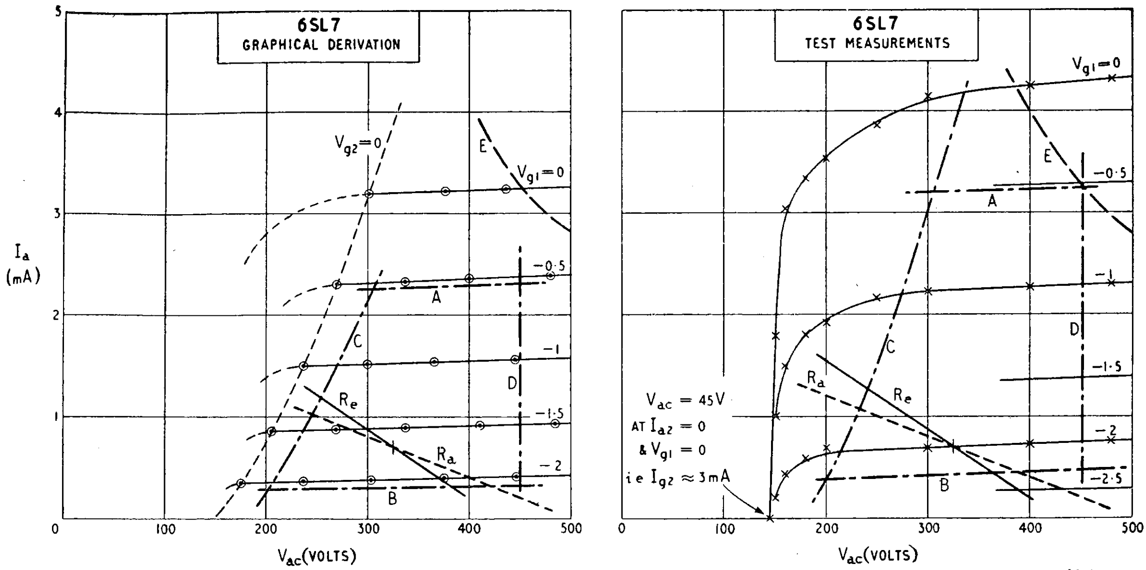
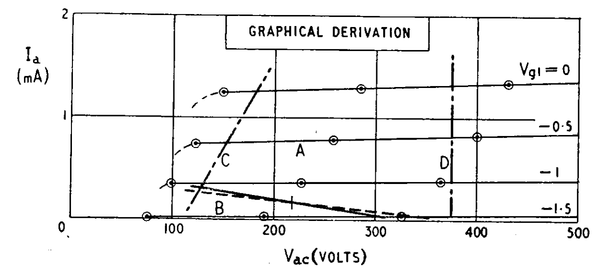
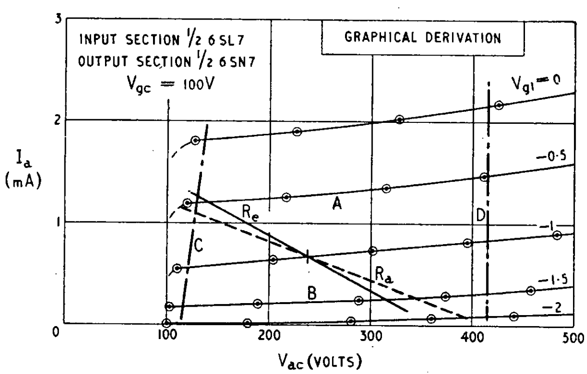


Fig. 6. (a) Graphically constructed, and (b) measured characteristics of 6SL7 cascode stage for $V_{gc}=150V$.



Above: Fig. 7. Cascode characteristics of 6SL7 with $V_{gc}=75V$.



Right: Fig. 8. Demonstrating the advantage of a low-impedance "upper" section ($V1=\frac{1}{2}$ 6SL7, $V2=\frac{1}{2}$ 6SN7) $V_{gc}=100V$.

D, V_{ac} max. = (for all practical purposes) V_{gc} + rated V_{a2} max. which in normal usage denotes the maximum supply voltage. Some liberty can usually be taken with this limit, but on the other hand noise is liable to increase with V_a and this should be taken into account in low-level stages.

E, W_{a2} max. This is for all practical purposes the W_{a2} curve shifted by V_{gc}.

Fig. 5(a) presents the graphical derivation of the characteristics of a 6SN7 cascode stage, and Fig. 5(b) displays the results of test measurements made on a 6SN7 valve of RCA manufacture chosen at random. The agreement of the two curves is good and any load line chosen from the derived curves is satisfactory when transferred to the measured curves, if permissible tolerances are borne in mind.

Fig. 6(a) presents the graphical derivation of the characteristics of a 6SL7 cascode stage, and Fig. 6(b) the results of test measurements. The agreement is good for μ and, although the measured valve runs at a higher current, g_m is only 15% high. Again, any load line chosen from the derived curves is satisfactory when transferred to the measured curves. A load line R_e = 150 kΩ, representing the following grid resistor R_g = 400 kΩ, in parallel with the anode load R_a = 250 kΩ, is drawn on both curves. This demonstrates the importance of adjusting such critical circuits to designed anode current rather than to grid bias voltage.

Low values of V_{gc} are sometimes useful. Fig. 7 shows the cascode characteristics of a 6SL7 at V_{gc} = 75 V when, with an anode resistor of 1 MΩ and following grid resistor of 2 MΩ, the gain is approximately 400 and the safe peak output voltage is at least 60 V.

Fig. 8 shows that there are advantages in using an upper section of low impedance if the largest possible output voltage is required with modest h.t. supply and values of R_a and following R_g appropriate to an output stage.

The graphical determination of the cascode curves, given any pair of triodes, is quickly made and presents a clear picture of the properties and limitations of that cascode pair. The determination of the cascode characteristics by the use of formulæ is less accurate unless tediously repeated for many points from data which have in most cases to be found by measurements made on the triode curves. The formulæ, however, do supply the quickest estimation of the dynamic properties of a cascode pair provided the appropriate values are inserted. It is easy to choose the appropriate values by reference to the foregoing.

The general formulæ are included here for completeness; subscripts 1, 2 and c denote respectively lower section, upper section and cascode.

$$\mu_c = \mu_1(\mu_2 + 1) \quad \ldots \quad (3)$$

$$r_{ac} = r_{a1}(\mu_2 + 1) + r_{a2} \quad \ldots \quad (4)$$

$$g_{mc} = g_{m1} \frac{\mu_2 + 1}{(\mu_2 + 1) + \frac{r_{a1}}{r_{a2}}} \quad \ldots \quad (5)$$

It is as plain as an outdoor aerial that the analogy with tetrodes must be neither taken for granted nor pressed too far.

The author wishes to record his debt to the Principal of Woolwich Polytechnic for experimental facilities, and would refer readers to the article by "Cathode Ray" on "The Cascode," W.W., Aug. 1955, p. 397, and to the articles mentioned therein.

Fish-Finding Asdic

ECHO sounders, designed primarily to show depth of water, have been used extensively in fishing vessels to detect shoals and even individual fish; but many valuable catches must have been missed because there has been no means of revealing fish other than those which pass immediately below the keel. By scanning in a horizontal plane with supersonic pulses, on the same principle as that used in the asdic submarine detection equipment, a much wider sea lane can be swept for fish.

Kelvin Hughes have now produced a prototype fisherman's asdic for this purpose with a range up to 2,000 yards which has given promising results in sea trials.

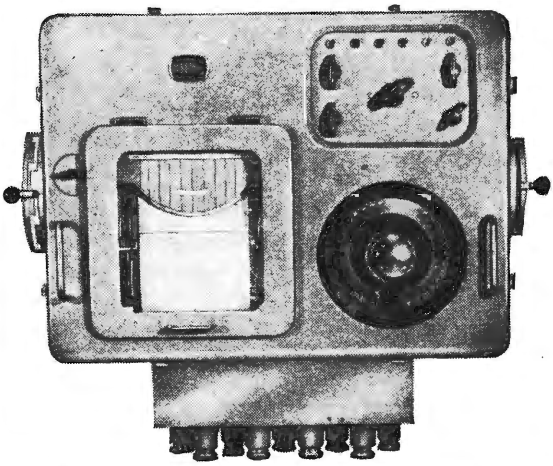
The pulse transmitter and receiver unit (transducer) is mounted on a vertical column working through a gland in the ship's hull and can be retracted into a fairing when not in use. It can be rotated by remote control in 5° steps and an automatic mechanism can be set to advance the bearing by this amount at each pulse when making a sweep. The beam width is 10° and the pulse train is at 50 kc/s (1 kW) with alternative durations of 1 and 10 milliseconds.

A heterodyne receiver circuit may be used with headphones or loudspeaker for watch keeping, and the output can be switched to a recorder for accurate ranging when an echo is to be investigated.

Some degree of skill and experience is required if full advantage is to be taken of the information provided by this equipment. There are many sources of echoes, including scattering from the bottom, the water surface in rough weather, and the wakes of other vessels in otherwise smooth water.

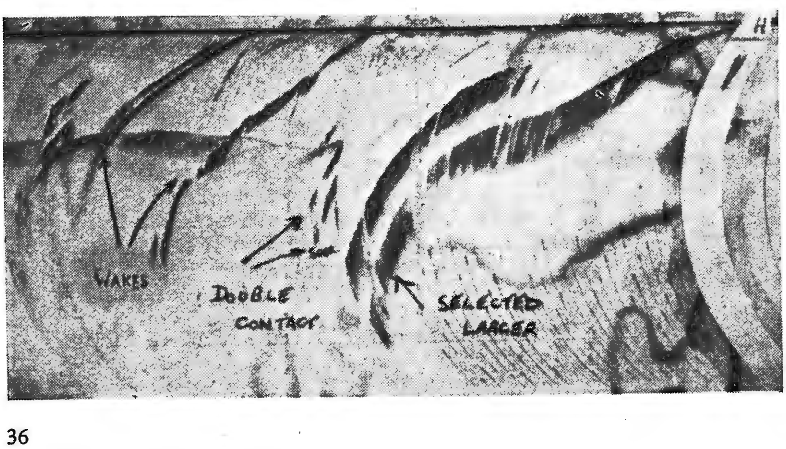
The accompanying specimen record shows, in the left-hand half, the traces of wakes which decrease in range until they are crossed (at the zero line running along the top). The horizontal echo running through the wake traces is from the sea bottom. In the middle of the picture may be seen the first contacts with two shoals followed by a change of range scale as the distance is closed: the difference in size of the shoals can be clearly seen. The curved dotted traces in the bottom right-hand corner are due to interference from the ship's echo sounder which was also working.

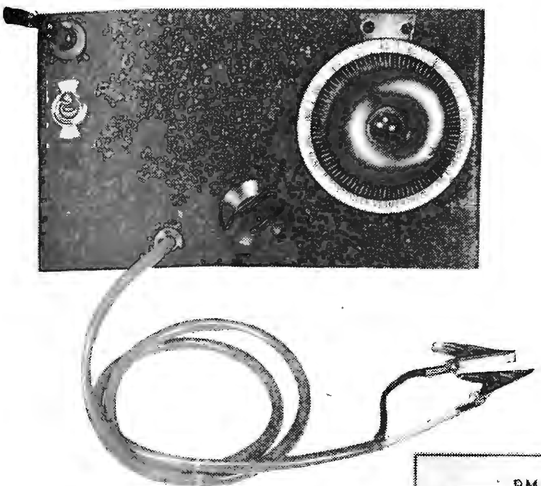
Given reasonable weather and intelligent operation, there is little doubt that this new equipment is capable of showing considerable economies in steaming time in search of fish, which will more than offset the initial cost (of the order of £2,500).



Wheelhouse control unit of the Kelvin Hughes fisherman's asdic. The beam bearing scale is on the right.

Shown on the right is the transducer unit which has a beam width of 10° at 50 kc/s. Below is a specimen chart showing two large fish shoals. The discontinuities are the result of alterations in the range scale.

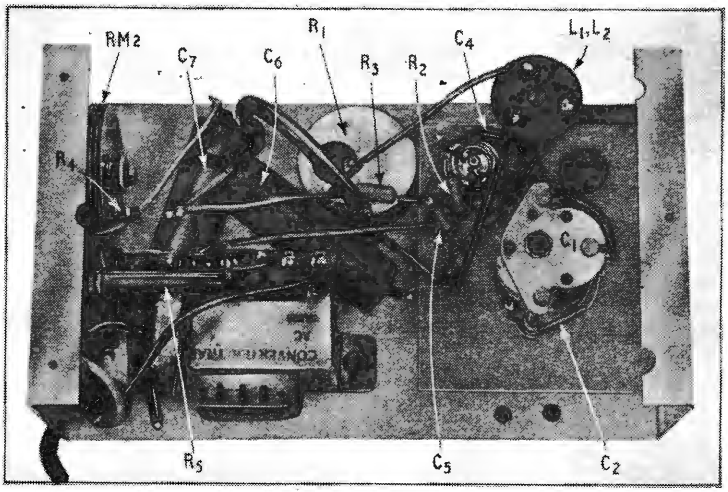




Simple V.H.F. Test Oscillator

Minimum Requirement for Aligning an F.M. Receiver

By BERNARD DRIVER



General view of the oscillator removed from its case. All the components are readily identified.

THE lack of some form of signal generator can be an insuperable difficulty when contemplating the alignment of a v.h.f. receiver. It is, perhaps, not generally realized that a simple oscillator, as described in this article, if judiciously handled will enable a satisfactory alignment to be achieved.

The basis of the circuit, which is shown in Fig. 1, is that described by H. B. Dent in the December 1952 issue of *Wireless World.* Instead, however, of employing separate oscillator coils and valves for signal and intermediate frequencies a single Hartley oscillator is used, the 90-Mc/s range being provided by harmonics. Since modulation was not considered essential, the transitron modulator is omitted, but there is ample space for the additional valve and components inside the case, which measures $7\frac{1}{2}$in $\times$ $4\frac{1}{2}$in $\times$ $2\frac{1}{2}$in, if the refinement is required.

The oscillator coil consists of 38 turns of 26 s.w.g. enamelled wire on a $\frac{1}{2}$-in diameter former, tapped 7 turns from the earthy end. The r.f. output is taken from a separate pick-up coil, consisting of a further 3 turns, spaced $\frac{1}{8}$in from the earthy end of the oscillator coil. Full winding details of the coil will be found in the article to which reference has already been made.

The valve is an acorn triode, Type 955, and in order to save space the connecting wires to the valve are soldered direct to the tips of the valve pins, a heat shunt being attached to each pin whilst applying the soldering iron. The writer has found that a sliver of ice is an efficient substitute for the crocodile-clip type of heat shunt, where space does not permit the latter's use.

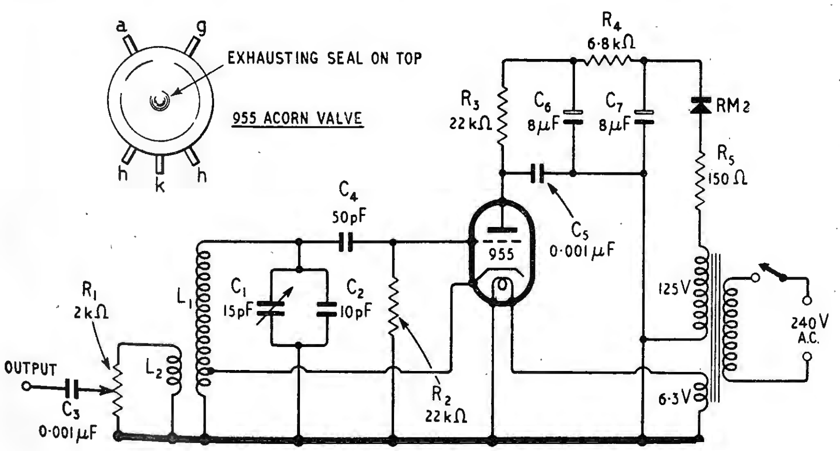


Fig. 1. Theoretical circuit diagram of the v.h.f. test oscillator.

The instrument can be calibrated with a fair degree of accuracy by the following method, which requires only a v.h.f. receiver capable of receiving the B.B.C. transmissions, and whose i.f. stages are tuned, at least approximately, to 10.7 Mc/s.

The first step is to plot the oscillator dial readings against fundamentals in the range 9.5 to 12 Mc/s. Connect the output from the oscillator, with 2-kΩ potentiometer (R_1) at maximum, to the aerial socket of the receiver. If the receiver has an i.f. trap in the aerial circuit, short it out. Upon tuning C_1 between maximum and minimum capacitance a number of responses will be heard. The i.f. fundamental can be readily identified since manipulation of the receiver tuning control will not tune it out.

The capacitance given for C_2 is approximate only, and if the fundamental cannot be found initially it may be necessary to try a different value capacitor.

In the unit constructed by the writer, the calibrated portion of the scale occupies about 60 degrees only, and it might be found desirable to apply band-spreading by reducing the value of C_1 and increasing that of C_2. This would facilitate making, for example, a point-to-point measurement of a discriminator characteristic of sufficient accuracy to indicate quite a small degree of non-linearity. Figs. 3 and 4 are actual curves plotted with this oscillator.

Having noted the position of the i.f. fundamental on the oscillator tuning dial, with the aerial as well as the oscillator output, connected to the receiver input socket as before, and with the receiver tuned to the Home Service, slowly increase C_1 until a beat note is heard in the loudspeaker. This will be due to the 9th harmonic of the oscillator fundamental beating with the broadcast signal. It is easier to tune the oscillator to the null point of this beat note when the broadcast carrier is not modulated, and it may be necessary to reduce the output from the oscillator to avoid swamping the receiver. Having found the null point, the oscillator dial reading may be plotted against the fundamental, which is $f/9$ where f is the carrier frequency of the test signal.

Then tune the receiver to the Third and Light programmes successively, repeating the process outlined above by slowly increasing C_1 to produce a beat note in each case, plotting the results after dividing the respective carrier frequencies by 9, as before.

Now reset the oscillator dial to the reading originally noted, giving the intermediate frequency of the receiver. Leaving the latter tuned to the Light programme, slowly decrease C_1 until the first beat note encountered above the intermediate frequency is heard. This will be the 8th harmonic of the oscillator fundamental, and when the null point has again been found, the dial reading may be plotted against frequency using the formula $f/8$. Retune the receiver

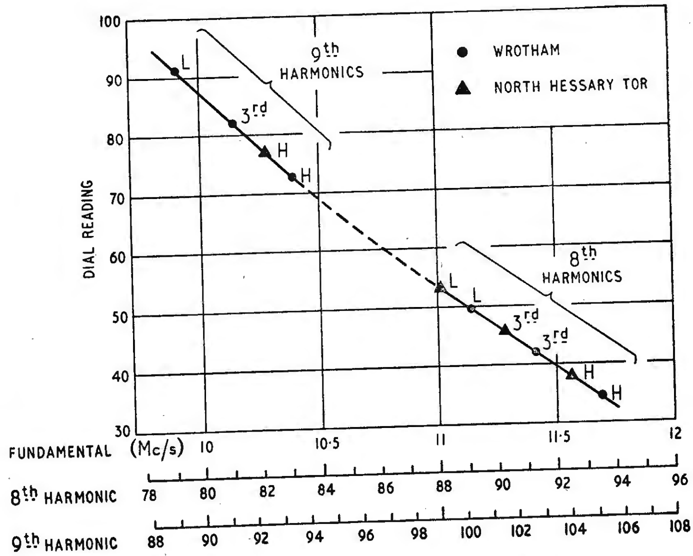


Fig. 2. Frequency calibration curve obtained by plotting the 8th and 9th harmonics of the oscillator beating with the Home, Third and Light programmes of Wrotham and North Hessary Tor. The fundamental is deduced from these readings.

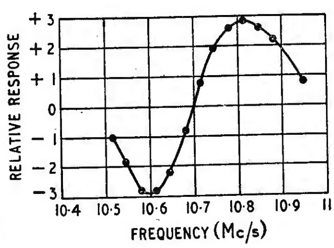


Fig. 3. A ratio-detector characteristic curve plotted with this oscillator.

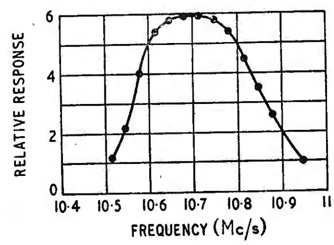
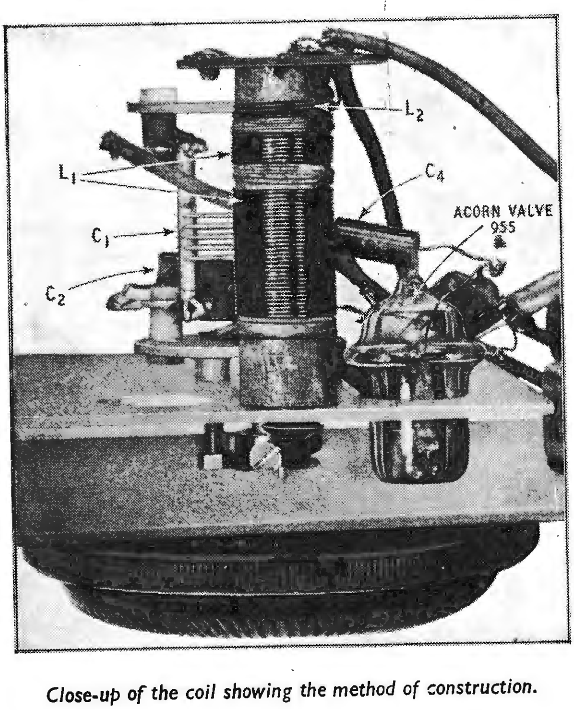


Fig. 4. Overall frequency response of the i.f. amplifier of an f.m. receiver.



Close-up of the coil showing the method of construction.

to the Third and Home transmissions successively, reducing C_1 to produce beat notes and plotting the dial readings as before.

By joining up the three points plotted from the 9th harmonic, and the three points plotted from the 8th harmonic, two curves will now be obtained, and assuming that the receiver has throughout been tuned to one or other of the transmissions from Wrotham, these will probably be similar to the curves shown by solid lines in Fig. 2. Here, however, additional points were obtained from North Hessary Tor.

It now remains to connect the two curves, as shown by the dotted portion in Fig. 2. This, as will be seen, is bound to be an approximation, but assuming a reasonably linear characteristic a fair degree of accuracy will be achieved if the dotted portion is drawn as a straight line. In addition, either end of the completed curve may be extended, if required, either notionally or by using as reference points the carrier frequencies of any other receivable v.h.f. transmissions. A v.h.f. scale can be added along the base line of the calibration chart as shown in Fig. 2.

The frequency stability of the oscillator is good, apart from a slight positive drift which takes place during the warming-up period. As the extent of this drift depends largely on the nature of the coil former, compensation can be effected by selecting a negative temperature coefficient capacitor for C_2, or possibly a combination of capacitors having negative and positive characteristics. The direction of drift can readily be ascertained by heterodyning a harmonic of the oscillator with a carrier of known frequency stability in the manner described earlier in this article. If, after setting C_1 to the null point, the frequency of the beat note changes, and it is necessary to decrease C_1 to restore the null point, the temperature coefficient of the circuit is clearly positive, and *vice versa.*

COMMERCIAL LITERATURE

Ferrite Cores for various applications, as well as iron-dust and flake-iron cores, are among the materials and components described in an illustrated brochure devoted to the products of the Chemical and Metallurgical Division of Plessey. Applications as well as physical properties and parameters are discussed. Obtainable from the Company at Wood Burcote Way, Towcester, Northants.

Germanium Diodes and Transistors.—The Telefunken manual mentioned in our last issue can be obtained from Tellux, West Mall Works, 27-29, Rabbit Row, London, W.8, who are agents for these products in Great Britain.

Components and Accessories, including coil packs and turrets, and drilled chassis and kits of parts for popular receivers and amplifiers. A general catalogue, with many detailed drawings, from Denco (Clacton), 357-9, Old Road, Clacton-on-Sea, Essex, price 9d.

Record Changer in which the required speed, record size and appropriate needle are all selected in one movement by a single control device. Improved version of an earlier model, with heavy turntable, new removable pick-up arm with ceramic crystal cartridge, and lower overall height. Brochure on the RTW-6 from Luxor Radio, Motala, Sweden.

Oscilloscope, with 3½-in p.d.a. tube, suitable for pulse and television work. The Y amplifier has a response to 6Mc/s with no overshoot or ringing and a sensitivity of 50mV per 0.8-cm graticule division. Time base, triggered or repetitive, variable from 0.2sec to 3μsec. Specification and description on a leaflet from Telequipment, 313, Chase Road, Southgate, London, N.14.

Relays by various manufacturers, including aerial, co-axial, polarized, galvanometer and other special types. Illustrated leaflet giving brief specifications of about 70 different models, from Radio-Relais, 18, Rue Crozatier, Paris 12, France.

Low Frequency B.F.O. covering 2c/s to 4kc/s in two ranges, on logarithmic scale, which can be swept automatically at predetermined rate by flexibly coupling tuning capacitor to pen recorder or other motor. Automatic output regulator maintains constant output to within 1 or 2 dB. Output impedance 6, 60, 600 or 6000 ohms. Leaflet from B & K Laboratories, 59, Union Street, London, S.E.1.

Moulded Knobs, Handwheels and Dials.—An illustrated catalogue from the British Electric Resistance Co., Queensway, Enfield, Middlesex.

Television and F.M. Distribution System (Dumec) for hotels, showrooms, etc. A range of accessories, including attenuators, filters and outlet boxes, has been developed for extending the system and is described in a leaflet from Rainbow Radio Manufacturing Company, Blackburn, Lancs.

Equipment Handles of simple design in brass, chromium plated or gold oxidized, with 2 B.A. tapped holes. Leaflet from Harwin Engineers, 101-105, Nibthwaite Road, Harrow, Middlesex.

Instrument Control Knobs and general purpose types. An illustrated leaflet showing the range available from Uncles, Bliss and Co., New Parade, Cherry Orchard Road, East Croydon, Surrey.

Midget Prefabricated Cabinets (Widney Dorlec), made up from basic components of slotted corner rods, thin side panels to fit in the slots and thick top and bottom panels (see our April, 1956, issue, p. 179). Illustrated brochure and price list of the various components from Hallam, Sleigh and Cheston, Oldfield Road, Maidenhead, Berks.

Fractional H.P. Geared Motors for slow speeds between 0.2 and 840 r.p.m. Also centrifugal electric pumps, extraction fans, sump pumps, mains transformers (including variable types), meters, sliding resistors and synchronous timing devices. Illustrated leaflets from M.R. Supplies, 68, New Oxford Street, London, W.C.1.

Tape Recorder, two-speed, with 4-watt amplifier and three loudspeakers—a 6-in elliptical type with two 2½-in treble units. Frequency response 50c/s-9kc/s at 3¾ in/sec and to 13kc/s at 7½ in/sec. Fast forward or rewind time: 1½ minutes. Description and specification of Model TK8-3D from Grundig (Gt. Britain), 39-41, New Oxford Street, London, W.C.1.

Components and Accessories; an illustrated catalogue for November, 1956, from Radiospares, 4-8, Maple Street, London, W.1.

CLUB NEWS

Bradford.—The meeting of the Bradford Amateur Radio Society on January 15th will be held at the Bradford Technical College where Dr. G. N. Patchett will speak on television. On January 1st G. F. Craven will discuss automation, and on the 29th A. Davies (G3INW) will deal with simple receivers. These two meetings will be held at 7.30 at Cambridge House, 66, Little Horton Lane. Sec.: F. J. Davies (G3KSS), 39, Pullan Avenue, Eccleshill, Bradford, 2.

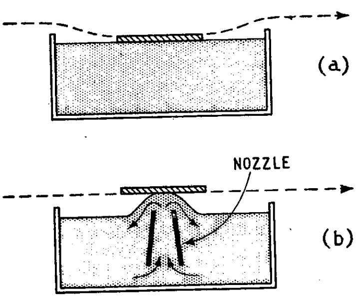
Leicester.—A symposium on mobile operation will be presented at the meeting of the Leicester Radio Society on January 14th. A fortnight later R. Macqueen (G3DVP) will speak about the Clapp V.F.O. on 28 Mc/s. Meetings are held at 140, Highcross Street. Sec.: J. Tranmer, 4, Grocot Road, Evington, Leicester.

Newbury.—At the meeting of the Newbury & District Amateur Radio Society on January 25th at 7.30 at Elliott's Canteen, West Street, L. A. Parnell (G8PP) will speak on world-wide commercial communication.

Wellingborough.—"Principles of radar" is the title of F. Wright's address to members of the Wellingborough and District Radio & Television Society at their meeting on January 3rd. On the 24th G. A. Wilford will deal with the principles of television. The club meets every Thursday at 7.30 at the Silver Street Club Room. Sec.: P. E. B. Butler, 84, Wellingborough Road, Rushden, Northants.

Technical Notebook

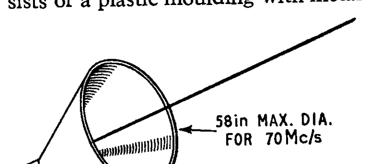
Improved "Dip" Soldering of printed circuits is offered by a new technique in which the work is not actually dipped as at (*a*) but passed continuously at 2-4ft per minute over a wave of molten solder forced up by a nozzle in the bath (*b*). This avoids the discontinuity of the dipping or rocking movements normally required and the consequent break in production flow. Fry's Metal Foundries, who have introduced a machine embodying this idea, claim that it allows flexibility in the rate of production and the size of circuit boards. There is positive expulsion of flux gases, freedom from trapped flux which may prevent wetting, and a reduction of "icicles" and "bridging." The stream of solder is consistently clean, and, being continuous, prevents surface cooling, thereby allowing a lower working temperature or a shorter contact period.

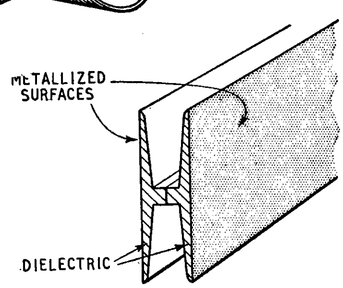


Wide Magnetic Tape, 1 inch across, seen at a recent E.M.I. electronics exhibition, was stated to be suitable for recording television signals. The composition was slightly different from sound-recording tape. An experimental television-on-tape recording equipment is being developed by the B.B.C. Research Department and details can be expected within the next few months.

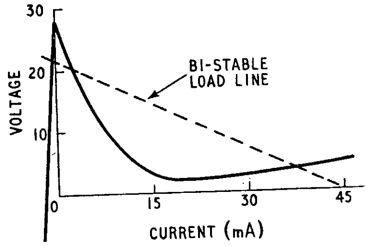
Symmetrical Transistors are rather rare devices in which the two outside electrodes have interchangeable roles. Each can act as either emitter or collector, depending on the polarity of the applied voltages. Only one commercially available version, the S.T.C. type TS4, appears in *Wireless World* "Radio Valve Data." Curiosity about possible applications was partly satisfied at the recent I.E.E. Ferrites Convention, when D. S. Ridler and R. Grimmond described a transistor access selector for their new drilled-block ferrite storage device (see Dec., 1956, issue, p. 596). In this selector the symmetrical transistors are used for gating both positive and negative pulses.

Open-sided Lines are the latest thing for simple and cheap transmission of r.f. energy. One example is a single-wire line connecting a remote aerial to a television distribution system (*Radio and Television News*, Nov., 1956). The characteristics are those of a coaxial cable with its outer conductor at infinity, and wave propagation is largely axial. The line is connected to ordinary coaxial input and output cables by means of large metal cones (see sketch) which make the transition between the "outers" and the infinite spacing. Losses, which increase with bends, are 10-20dB per mile, and intermediate amplifiers are needed to cover the 15-mile stretch. Another example is waveguide of H-shaped cross-section, open at top and bottom (*Electronic Industries*, Nov., 1956). Intended for millimetre waves, it consists of a plastic moulding with metallized coatings on the legs of the H (see sketch). Attenuation decreases with increasing frequency, and less than 0.1% of the energy travels outside of the guide. Fabrication and jointing are simple.





Negative-Resistance Transistor recently introduced by General Electric in America has a characteristic like a point transistor that will give a regenerative switch-over action in bistable switching and computing circuits (see figure). At the same time it has the uniformity, stability and reliability of a junction type. The Unijunction transistor, as it is called, is made from silicon and so can be operated at high temperatures. Because of its characteristic it will do the work of the two junction transistors normally required in a bistable trigger circuit. This should make possible a considerable simplification in the design of switching and computing equipments using large numbers of transistors, with consequent reduction of size and cost.



Binary *v.* Decimal notation was discussed by Dr. M. V. Wilkes at a recent I.E.E. meeting on data processing equipment. Many people have assumed that the decimal form is more suitable for data processing since very little computing is involved, and conversion to and from binary is a waste of time. Dr. Wilkes stressed, however, that a paramount problem in many data-processing systems is that of storing large quantities of information, and this can be done a good deal more efficiently by binary techniques.

Transistor Biological Amplifiers have distinct advantages over those using thermionic valves because of low microphony—normally a source of trouble on biological recordings. Moreover, their compactness allows them to be operated very close to the subject. This avoids the need for long input leads which can pick up interference and mask the required waveform. A four-stage transistor pre-amplifier for electromyography with a noise output of only 15μV is described by R. E. George in Vol. 7, No. 1 of the *Proceedings of the Electro Physiological Technologists' Association.*

Telephone-line Television, made possible by slow scanning, illustrates the communication theory principle that you can transmit a lot of information in a narrow-bandwidth channel if only you take sufficient time over it. In one system, developed by Thompson Products for transmitting still pictures of documents (*Electronics*, Nov. 1956), the scanning rate is 2-7 complete

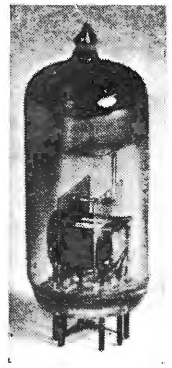
pictures per second, and to allow for this a long-persistence c.r.t. is used at the receiving end. A horizontal resolution of 300 lines is possible with an 8-kc/s bandwidth. In the Bell Telephones "Picture-phone" system (see illustration) the camera scanning is comparatively fast at 20 pictures per second, but the actual transmission rate is only 1 picture in 2 seconds. The picture selected in each 2-second period is recorded on a magnetic drum, then, by means of gating and timing circuits, is "read" off at 1/40th of the recording speed, taking 2 seconds in transmission. This requires a line bandwidth of only 600c/s. At the receiving end are two storage type of c.r.ts, one of which builds up the incoming picture while the other displays the previous picture.

Silicon Transistors, capable of working at high temperatures (up to 150°C), are the next thing to watch for on the British market. Meanwhile, two new types have been introduced by Texas Instruments in the U.S.A.—the *n-p-n* 2N117 and 2N118. Suitable for high-gain, low-level applications, they have been designed to meet the stringent requirements of the U.S. Navy. The testing includes heat cycling four times from −55°C to +150°C and storage for 24 hours at 150°C.

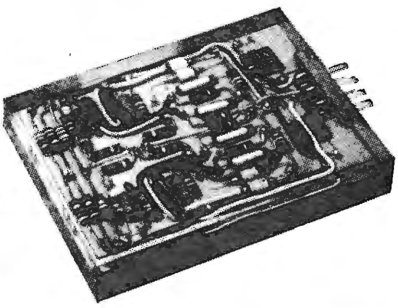
R.F. Silicon Transistors of tetrode construction have also been developed by Texas Instruments, for working up to 100°C. In a single-stage amplifier, a gain of 15dB can be obtained at 30Mc/s. Details of gain tests in the 5-30Mc/s region are given by R. R. Webster in the Nov., 1956, issue of *Electronic Industries.*

Flying-spot Scanning, first introduced by Baird in the early days of television, is now coming back for colour television. This is because the development of sensitive photo-multiplier tubes has made it possible to get video signals of good signal/noise ratio at the low light levels given by the scanning c.r.t. In the Du Mont "Vitascan" system, for example (*I.R.E. Transactions* PGBTS-6, Oct. 1956), clusters of 5-in photo-multipliers with colour filters are disposed about the studio, and can be arranged to get "lighting" effects as if they were light sources. During scanning the studio has to be completely dark, but a form of lighting can be provided by pulsing lamps in the frame suppression periods. The system is more suitable for low-cost industrial television, but has certain advantages for broadcasting; e.g., no high-power studio lighting and air-conditioning required, good colour match between different scanners (since the photo-multipliers are common to them all) and short warm-up and adjustment time.

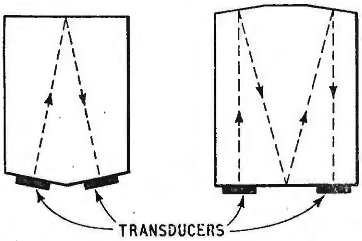
U.H.F. Receiving Valves for Bands IV and V are now coming on to the market—colour television and mobile radio being two likely future applications. One might expect such valves to look rather unusual. In fact they are just like conventional B7G and B9A miniature types, except for the planar type of electrode structure inside. A recent one from G.E.C. is the A2521, a low-noise triode suitable for use as an r.f. amplifier in the 500-1,000-Mc/s region (see picture). Its slope is notably high at 12 mA/V, and the noise factor varies between 9 and 12 dB, depending on the frequency.



Transistor Decade Counter, made as a potted plug-in unit by Venner Electronics (see photograph) is notable for its small size (4½in × 3¼in × ¾in) and low consumption (160mW or 100mW, depending on whether it is used as a counter or as a ÷10 frequency divider stage). The circuit consists of four bi-stable trigger circuits with feedback and will operate at pulse input frequencies up to 30kc/s. A resetting facility (to zero or to nine) is included. The 86 components are mounted on a double-sided tagboard in the potting resin.



Folded Delay Lines of the acoustic-wave type are being developed by Bell Laboratories for giving long delays at radio frequencies (around 15Mc/s) in a relatively small space. The advantage over electrical delay lines is simply that acoustic waves travel some 100,000 times slower than electromagnetic waves, and this in itself makes possible much smaller equipment. Solid blocks of vitreous silica are used, with quartz or barium titanote input and output transducers, and the folding of the wave path is achieved by reflections inside the specially shaped block, as shown in the sketches. One 990-μsec line utilizes 30 reflections to fold up some 12ft of wave path into a polygon 5½in in diameter. With a centre frequency of about 15.5Mc/s, this delay line has a bandwidth of over 4Mc/s.



Better reproduction from discs is offered by a tape-recording technique suggested by W. E. Gilson in *Electronics* for July, 1956 (p. 125). Signals initially recorded on magnetic tape are played back at half speed. The upper frequency limit is thus halved. These signals are re-recorded on an ordinary disc recorder which is also run at half speed. Effects such as cutter head resonance which normally cause distortion or loss at the higher frequencies will then occur outside the range to be recorded. On finally playing back the disc at normal speed the original signals are thus reproduced without distortion due to these effects.

Complications may, however, occur at the lowest recorded frequencies. The maximum amplitude that can be recorded on the disc is, of course, limited. Thus either the low-frequency turnover point for recording on the disc will be the same as usual, in which case this frequency will be twice the normal on final playback; or the disc recording must be made at half the usual level and the increase in noise may be troublesome. Distortion at the lowest frequencies on the disc recording must be more strictly controlled as this will be more objectionable on playback when the frequency is doubled. The disc recorder must be free from rumble even when played at half the normal speed, and, due to the re-recording, wow and flutter requirements will also be more stringent.

NEGATIVE RESISTANCE

A Mystery of the Backward Bending Curve

By "CATHODE RAY"

SOME while ago Thomas Roddam posed a very interesting question*. Interesting, that is to say, to those who, like myself, are intrigued by questions which seem at first sight to imply something contradictory in accepted theory, but no doubt irritating to the "practical" folk who regard such things as mere hair splitting and a waste of time. Personally I don't think it *is* a waste of time, even for a practical man, to look into any apparent contradiction. If there really is something wrong with accepted theory, then the sooner it is put right the better; but if (as is considerably more likely) it is only our view of it that is wrong, then that is a good thing to put right, too.

Suppose we pass various amounts of current through a resistor, and in each case measure the voltage between its terminals; then (provided we take care to keep the temperature of the resistor constant) we usually find that a graph of voltage against current, such as Fig. 1, is a straight line. We conclude, as did Dr. Ohm long before us, that current and voltage are directly proportional to one another, so that the ratio V/I for any particular resistor is always the same, no matter what the values of V and I. This ratio has become quite well known as "resistance," denoted by R. We can easily see that with any given graph scales it is proportional to the slope of the graph. The line is, in fact, often regarded as representing the resistance. But for ordinary resistors there is really no need to make a graph; the value of R in ohms (i.e., volts per amp) provides all the needed information.

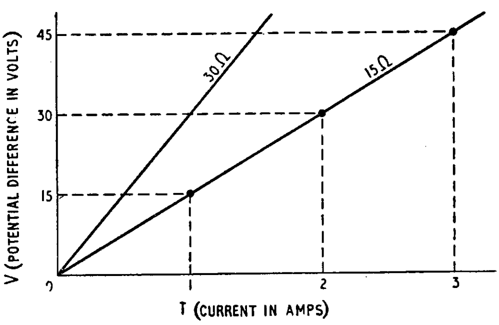


Fig. 1. Graph of voltage drop against current for ordinary linear (ohmic) resistance.

While this "law" established by Ohm still holds good for a sufficiently large number of parts of electrical circuits for it to be extremely useful, the number of parts for which it does not hold good has tended to increase rather noticeably of late. I have it on American authority† that already 7,000,000,000 valves have been manufactured, and every one of them flagrantly disobeys Ohm's law. So far only a very few million transistors have been produced, but Dr. Shockley has predicted an "explosive" increase very soon. And think, if you can, of all the metal rectifiers and neon tubes and Metrosils and much else. For any of these, the value of V/I varies with the values of V and I and also with the starting points from which they are measured; so the resistance is a variable, and a graph is necessary to provide full information about it. This is where the slope of the graph as a measure of resistance comes in useful, for the way in which the resistance varies can be seen at once from the variations in slope of the voltage/current graph, without having to plot from it a resistance/current or resistance/voltage graph. (There is another way of reckoning the resistance at any point—as the slope of the straight line drawn from it to the origin—but that is seldom used in practice.)

It is because of the curvature of their voltage/current graphs that electronic devices are called non-linear. But although their curves may vary from almost horizontal, meaning nearly zero resistance, to almost vertical, meaning nearly infinite resistance, it is usual for the slope to be everywhere upward from left to right‡, meaning that the resistance is always positive. There are, however, a few exceptions in which the slope bends over the other way, as in Fig. 2, so that over a certain range of current and voltage the resistance comes out negative.

Users of valves and other non-linear devices are commonly interested in what can be done with them

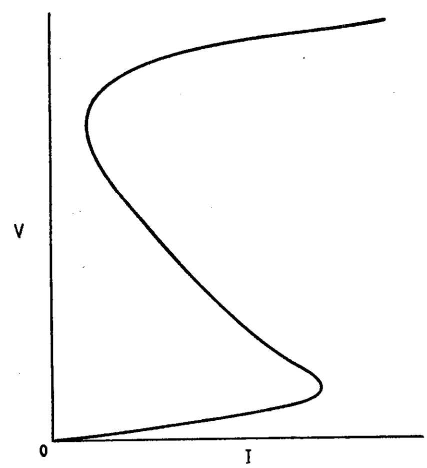


Fig. 2. Graph of voltage drop against current for one kind of non-linear (non-ohmic) resistance. The resistance varies with voltage, and over a certain range is negative.

* "Negative Resistance," *Wireless World*, July 1954, p. 336.
† D. G. Fink, "Transistors v. Vacuum Tubes"; *Proc. I.R.E.*

‡ Assuming, of course, the standard practice of making the scale numbers increase positively to the right and upwards.

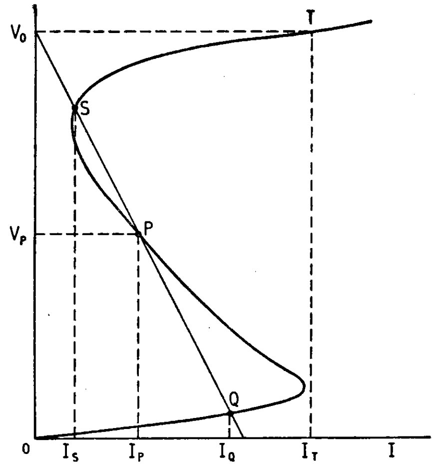


Fig. 3. Diagram combining graphs of non-linear resistance (as in Fig. 2) with linear resistance in series. In this case there are three ways (represented by P, Q and S) in which a total voltage V_0 can be shared between them.

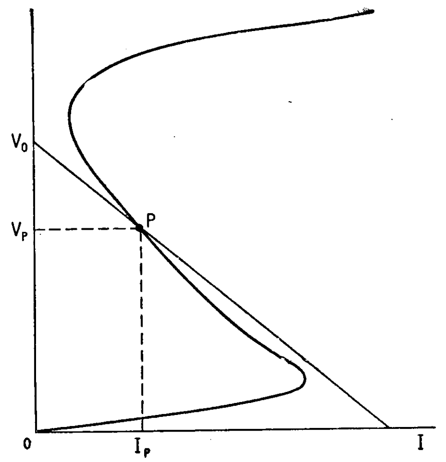
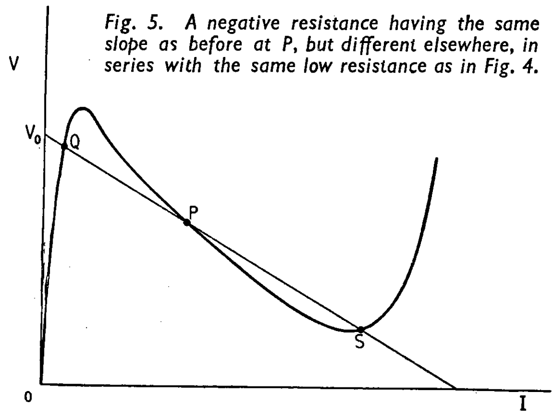


Fig. 4. Here the non-linear negative resistance of Figs. 2 and 3 is in series with a lower resistance, and there is only one way of sharing V_0.

Fig. 5. A negative resistance having the same slope as before at P, but different elsewhere, in series with the same low resistance as in Fig. 4.



in combination with a linear resistance connected as a load in series with a fixed supply voltage. This situation can conveniently be studied by drawing a "load line" on the same diagram as the valve curve, as for example in Fig. 3. The technique is well known, but for beginners I explained it in the July 1955 issue. The only point I need perhaps repeat here (in view of my having just said that a slope downwards towards the right represents a negative resistance) is that the load line sloping downwards towards the right does *not* mean that its resistance is negative. The apparent contradiction is because the point where the load line cuts the voltage scale (e.g., V_o in Fig. 3) represents the total fixed voltage applied to it and the valve in series, so the voltage across the load resistance is zero at that point and increases in the opposite direction to the scale numbering.

Because the valve and the load resistance are in series, the same current must flow through both; and so this amount of current on the diagram must apply to both curve and load line. At the same time the voltages across them must add up to the total V_o. These two facts can apply only to a point which is on both load line and curve at the same time as P in Fig. 3. This point indicates that the voltage across the valve is V_p, the voltage across the resistance is V_o-V_p, and the current through both is I_p.

Three-point Intersection

If this were a normal kind of valve, with resistance positive throughout, there could be only one point common to both its characteristic curve and any other positive resistance load line. But the valve we are considering is one of the exceptions with a stretch of negative resistance, which makes it possible for the load line to cut its curve at three points, as shown. In such cases there are two alternative currents, I_q and I_s, that could be driven through the combination by the same total voltage. At both of these other intersections the valve resistance is positive and the situation is entirely normal; the only question that arises is how the valve and resistor decide between them which point to occupy.

Actually they haven't much choice, because it is imposed on them from without by whoever is responsible for the arrangements for switching on. In the ordinary way, with the current growing from zero, it would rise to Q and stay there. But if now the resistor is short-circuited, changing the load-line slope to zero, the working point becomes unambiguously T. If the resistor is then unshorted the working point slides down to S.

So much for Q and S; but how can one get to P? It is not really very difficult; one just connects the junction of valve and resistor straight to a source of V_p volts. When this connection is broken the working point should remain at P. It we try it, however, we find it invariably flips over to Q or S. Why?

Most treatises beg this question by stating that P is an unstable working point. Before we try to find a real answer let us just look at Fig. 4, where our kinked valve curve appears yet again, this time in conjunction with a lower load resistance. Here, the negative resistance introduces no complication; there is no alternative to P as the working point, and only one value of current (I_p) can cause the total voltage drop to be V_o.

Clearly, the situation changes from unstable to stable when the slope of the load line changes from greater to less than that of the valve at the point P.

Next, let us give our attention to Fig. 5, where the slope of the load line is less than that of the valve at P, just as in Fig. 4, but where nevertheless there are three alternative points, and the situation is presumably unstable, as in Fig. 3. Experiment confirms this. If in each case the arrangement is switched on in such a way as to start it at point P, with a V/I characteristic as in Fig. 4, it stays there, but in Fig. 5 it flips across to Q or S the moment it is released. The point is—as T. Roddam pertinently asked—how does the circuit know, when it is set to point P, whether it is stable or unstable? If only the parts of Figs. 4 and 5 in the immediate neighbourhood of P are disclosed there is no difference whatsoever between the two diagrams.

The Working Point's Dilemma

I thought this a remarkably intriguing problem. Unfortunately, Mr. Roddam had to hurry on to the kernel of his article, which was the negative impedance converter, and so it appeared that the working point has to find out whether to say at P or not by doing tricks with a piece of string around a stick. The explanation, like most conjurors' explanations of how their tricks are done, left me wondering harder than ever; so, in case there were any other readers in the same state, I will offer my less elegant attempt to find the way.

The first thing is that theoretically a simple combination of positive and negative resistance must stay at P either way. The reason is that the only possible conditions are those represented in the diagrams by points common to both graphs—the valve curve and the load line. It is not possible to get from P to Q or S—or indeed anywhere—in such a way as to be on both graphs all the time. To move from P it would be necessary for the current or voltage or both to have two different values at the same place and the same time—which is absurd.

A way out is to alter the circuit. And perhaps it is high time to see a practical circuit diagram instead of just having to imagine a negative resistance. After my recent expositions you may expect a transistor as example, but point-contact transistors, which are the main ones with inherent negative resistance, are well on the way out. And since there must be many people to whom transistors of any kind are still something new and strange, I am first going back to the dynatron, which may seem a bit archaic to the younger readers, but at least is a valve.

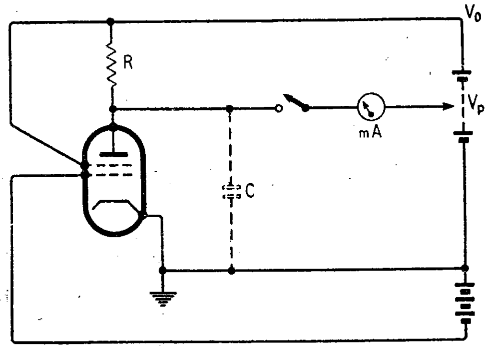


Fig. 6. Dynatron circuit for experimenting with the type of negative resistance graphed in Figs. 2-4.

As Fig. 6 shows it is tetrode, but *not* of the modern "kinkless" variety in which negative resistance is deliberately ironed out; rather, an old-fashioned "screen-grid" tetrode. The screen grid is held at a normal voltage, say 100; and if the anode voltage is varied from 0 to 100 the anode current traces out a curve like Fig. 2. This may not have been recognized as a dynatron curve, even by the old-timers, because it has been drawn with the voltage scale vertical instead of horizontal. The idea of departing from the usual custom was to follow Mr. Roddam in making slope represent resistance rather than conductance.

The reason for the abnormal behaviour of anode current while the anode voltage is varied between about 10 and 90 is that the electrons reaching the anode from the cathode have been given a boost on the way by the relatively high screen-grid voltage. So when they hit the anode they do so with such violence that they knock out some of the electrons already there. These "secondary" electrons are easily gathered in by the high positive screen-grid voltage against the feeble competition of the anode voltage. The result is that the more the anode voltage is increased the more violent the bombardment and the greater the number of secondary electrons, which all subtract from the normal anode current. In fact, it is quite usual for the net anode current to become actually negative over a certain range of anode voltage. When the anode is made nearly as positive as the screen grid, however, the secondary electrons have little or no inducement to leave, and the anode resistance becomes positive again.

One can—and usually does—produce one's negative resistance by means of positive feedback, but for the present purpose the dynatron has the great advantage that its negative resistance is practically constant at all frequencies right down to zero, and the circuit is almost ideally free from complications.

By choosing a suitable resistance for R, we can arrange that its line on the diagram cuts the valve anode characteristic curve in three places, as already discussed. And by joining a wire from the anode direct to a tap on the h.t. battery at the voltage of point P, we can bring the valve to that point. To make sure we are there, we can put a low-range milliammeter (mA in Fig. 6) in this wire and adjust the tap voltage until this meter reads zero. Seeing the wire is carrying no current, we might suppose that breaking the circuit would make no difference; but directly we do so, flip!—the current goes up or down, and we find it is at Q or S. How does it get over the hump in between?

Hidden Component

An explanation can be found in one of those "invisible components"—the capacitance of the anode to other electrodes. Most of it would be to the screen grid, but, since there is a fixed voltage between that and earth, the same results so far as voltage changes are concerned are obtained if all the capacitance (C in Fig. 6) is regarded as direct to earth; and it is rather easier to see what is going on that way.

However carefully we adjusted the voltage tapping, there would always be some current through that path when we opened the switch, if only as a result of the inevitable random fluctuations in circuits and valves. Suppose that just before breaking the meter

(*Continued on page* 45)

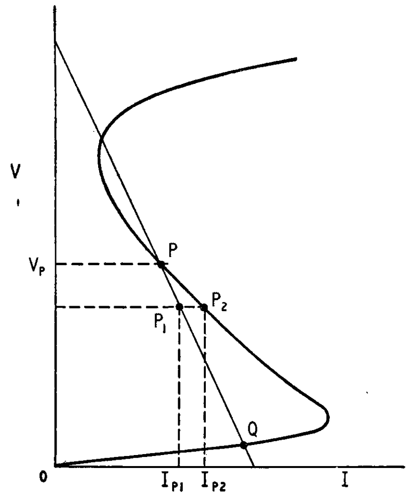


Fig. 7. Explaining the role of C in Fig. 6 in the instability of that circuit.

circuit there was a minute current flowing through it *into* the valve. The valve current would then be very slightly greater than through R; a condition represented rather exaggeratedly in Fig. 7 by points P_1 and P_2. The current through R would be I_{p1}; through the valve, I_{p2}; and the difference would be coming via the meter circuit. When the switch was opened there would be a sudden call for current to bridge the I_{p2}-I_{p1} gap.

This is where C comes to the rescue. But it can deliver this current only at the expense of its own voltage. Its own voltage is the same as the anode voltage, so that begins to drop, and in so doing widens the gap between P_1 and P_2. So more current is called for, and the gap widens more quickly. And so there is an accelerating movement towards Q. Directly P_2 gets past the "hump," the call for current, and hence the rate of voltage drop, begins to decline; until finally, at Q, there is no gap and no further drop in voltage.

With C of the order of 10pF, as it would normally be, the whole process is over in something like one microsecond, so it is difficult to follow by eye. This disadvantage can be overcome by augmenting C by a capacitor of say 16μF. The slowed-down changes of current from it and also via R can then be observed on suitable milliammeters when the switch is opened after initial setting to as near P as possible. If the error in setting to P is on the other side, the system makes for S instead of Q.

Fair enough; but how about the original problem? How does the system know, at the moment of opening the switch, that the valve curve doesn't bend the other way, as in Fig. 8, which in the region of P is identical with Fig. 7? A rare fool it would look, after rushing madly down as before, to find that Q was non-existent and that the gap, instead of closing up, ever widened, while the scope for filling it by the voltage across C falling was strictly limited—and even reversed!

It appears, however, that this trap would be sprung before the start. For directly we tried to set it to P by connecting the junction of R and the negative-resistance device direct to a source of V_p, as we did in Fig. 6, we would be up against the fact that with this other sort of negative resistance there would be a Q′ and an S′, to one of which the system would promptly go and stay. So our problem couldn't actually arise.

You may still feel, as I do, dissatisfied with this outcome, inescapable though it may be. It reminds one of the answer to the old problem of what would happen if an irresistible force encountered an immovable object—that there are no such things. You would like to know, I am sure, whether there is some fundamental difference between the negative resistances in Figs. 7 and 8 which makes itself felt at or near P, without having to go farther along to see which way the curve ultimately bends, and even without having to remember what kinds of difficulties there may have been in getting to P to start with.

An Odd Situation

We seemed to go some way to solving this mystery when we recognized the existence of C. It provided a most satisfactory explanation of our experimental results with the dynatron (Figs. 6 and 7). But it also seems as if it would lead to an extremely embarrassing situation if the negative-resistance slope happened to bend over the other way as in Fig. 8—a rapidly widening current gap to fill, and C at the end of its ability to supply it.

The best thing to do when theory predicts an absurdity like this is to try it in practice. This is where the old point-contact transistor comes in useful. Thanks to Mr. Betteridge of the G.E.C. I was able to obtain an experimental specimen, which

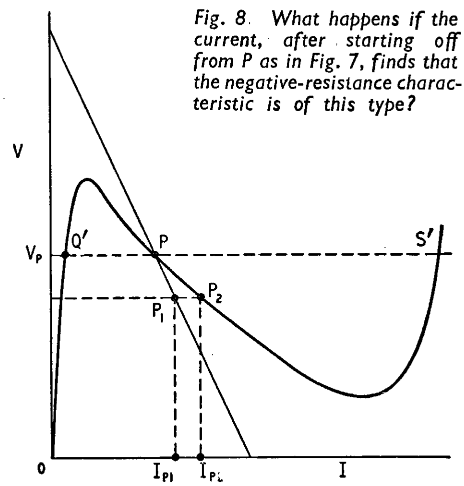


Fig. 8. What happens if the current, after starting off from P as in Fig. 7, finds that the negative-resistance characteristic is of this type?

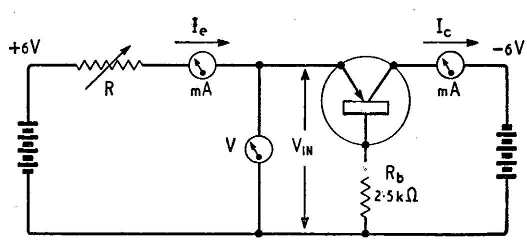


Fig. 9. Point-transistor circuit for providing negative resistance of the Fig. 8 type.

I connected in the simple common-base circuit shown in Fig. 9. Unlike the more usual common-emitter circuit (and the common-cathode valve circuit) its polarities are such that a bias resistance (R_b) causes positive feedback. Because each milliamp change in emitter current causes more than one milliamp change in collector current, the voltage drop in the emitter circuit due to the emitter-to-base positive resistance is more than offset by the reverse voltage drop across R_b due to collector current. By varying R, the relationship between input voltage V_{in} (measured on a currentless valve voltmeter V) and input current I_e was plotted, as in Fig. 10. Because the reverse drop across R_b was the main ingredient, V_{in} is wholly negative, but this doesn't matter; the shape of the curve is clearly of the Fig. 5 and 8 variety.

In Fig. 10 the load line for the particular value of R corresponding to 0.85mA and 2.0V is shown, giving the working point P. There is no alternative intersection to flip over to, so not surprisingly (from that point of view) this setting proved to be quite stable. But what, you may ask, about stray capacitance? Seeing that around P the relationship between negative and positive resistances is the same as in Fig. 7, which we found to be unstable, how (yet again!) does the system know itself to be stable?

One difference between the transistor circuit and the dynatron—besides the opposite curvature of the bends—is that the resistances are comparatively low, so very small capacitances have proportionately less effect; and another is that the amplification on which the transistor's negative resistance depends falls off at moderately high frequencies. So just to be sure that there was enough to make the thing unstable and start it off on an impossible journey I connected 300μF across the input.

There was no doubt about the effect. The circuit didn't blow up, but all the meter pointers see-sawed violently to and fro!

When I started, it was with the firm intention of arriving at a straightforward answer to the question. But the time is far spent, and so far from having cleared up that mystery we have unearthed another —what happens when the 300μF capacitor charge reaches one of the bends and finds it can (theoretically) neither go on nor can turn back, but somehow in practice does keep on turning?

Come to think of it, there is yet another. With the help of Fig. 7 we saw theoretically how capacitance across the dynatron ensures instability when the series resistance is relatively high, by cumulatively widening the slightest current gap between dynatron and resistance. When the experiment was made with an actual dynatron circuit, it behaved exactly as predicted by this theory. If now we consider in the same way the diagram for a transistor with low resistance, Fig. 5, we find that the current into or out of a capacitance across the transistor necessitates a voltage change which drives the working point P_1 and P_2 *towards* P, which means that the circuit is stable. In attempting to confirm this by experiment I found it quite a tricky business getting the low-resistance circuit anywhere near P to start with, and the result was invariably the same: it ended up at Q or S. At no time did it show the slightest inclination to be stable. Why did experiment confirm the capacitance theory in a dynatron circuit and contradict it in a transistor circuit?

It looks as if I shall have to get next month's issue to find out!

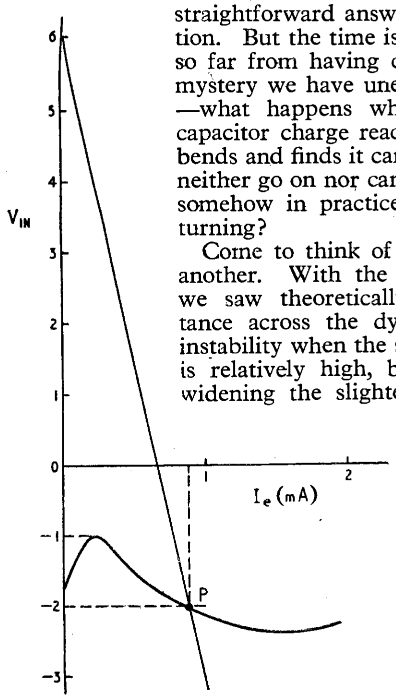


Fig. 10. Actual input characteristic of an experimental circuit as in Fig. 9.

High-Remanence Tape

A NEW grade of "Scotch Boy" magnetic recording tape has been introduced by the Minnesota Mining and Manufacturing Company which is of particular interest to high-quality enthusiasts. It is known as No. 120 and has a remanence of 0.9 lines compared with 0.6 lines for the No. 111 standard and No. 150 thin-based grades. The coercivity is 240 oersteds in all three cases.

The advantages conferred by the new tape are threefold. There is a 3-dB increase of sensitivity for a given input, the maximum input for a given distortion level (1% 3rd harmonic) can be increased by more than 3 dB giving an overall gain at maximum of 6 to 8 dB, or, alternatively, the input can be reduced to a level which gives the same volume as would be obtained from No. 111, but with harmonic distortion reduced by approximately 12 dB.

Like the standard No. 111 tape, the new "High Output" grade is on 0.002-in cellulose acetate base and is available in four spool sizes between 600 and 2,400ft. The cost is about 10% higher than standard tape.

Dates for Your "Wireless World" Diary

ANNOUNCEMENTS have already been made of the dates of many of this year's exhibitions and conventions, but for the convenience of readers we give below a list of the principal events in 1957.

Television Society Exhibition ... ... March 5–7
Royal Hotel, Woburn Place, London, W.C.1.

Physical Society Exhibition ... ... March 25–28
Royal Horticultural Society Halls, London, S.W.1.

Components Show (R.E.C.M.F.) ... ... April 8–11
Grosvenor House and Park Lane House, Park Lane, London, W.1.

Electrical Engineers' Exhibition (A.S.E.E.)... ... April 9–13
Earls Court, London, S.W.5.

Audio Fair ... ... April 12–15
Waldorf Hotel, London, W.C.2.

Instruments, Electronics and Automation Show... May 7–17
Olympia, London, W.14. ... ...

Scottish Radio Show (R.I.C.) ... ... May 22–June 1
Kelvin Hall, Glasgow.

Convention on Electronics in Automation ... June 28–July 2
(Brit. I.R.E.)
King's College, Cambridge.

Institution of Electronics Exhibition ... ... July 10–20
College of Science and Technology, Manchester.

British Plastics Exhibition* ... ... July 10–20
Grand Hall, Olympia, London, W.14.

National Radio Show (R.I.C.) ... ... Aug. 28–Sept. 7
Earls Court, London, S.W.5.

Farnborough Air Show (S.B.A.C.) ... ... Sept. 3–9
Farnborough, Hants.

British Sound Recording Association Exhibition* Sept. 20–22
Waldorf Hotel, London, W.C.2.

Radio Hobbies Exhibition (R.S.G.B.) ... ... Oct. 23–26
Seymour Hall, London, W.1.

*Conventions are held in conjunction with these exhibitions.

JANUARY MEETINGS

LONDON

8th. I.E.E.—"A theoretical and experimental investigation of anisotropic-dielectric-loaded linear electron accelerators" by R. B. R. Shersby-Harvie, L. B. Mullett, W. Walkinshaw, J. S. Bell, and B. G. Loach at 5.30 at Savoy Place, W.C.2.

9th. Brit. I.R.E.—A programme of films on radio and electronic engineering at 6.30 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

9th. Radar Association.—"The problems and techniques of high energy physics" by J. R. Atkinson (Glasgow University), at 7.30 at the Anatomy Theatre, University College, Gower Street, W.C.1.

10th. Society of Instrument Technology.—"Electronic automation of machine tools" by F. T. Lett at 7.0 at Manson House, Portland Place, W.1.

11th. Television Society.—"Automatic gain control circuits in television receivers" by S. N. F. Doherty and P. L. Mothersole (Mullard) at 7.0 at 164 Shaftesbury Avenue, W.C.2.

18th. B.S.R.A.—"Hearing aids and audiometers" by S. Kelly at 7.15 at the Royal Society of Arts, John Adam Street, W.C.2.

23rd. I.E.E.—"Junction transistor bootstrap linear sweep circuits" by K. P. P. Nambier and Dr. A. R. Boothroyd; "Design considerations for junction transistor oscillators for the conversion of power from d.c. to a.c." by F. Oakes; and "Minority carrier storage in semi-conductor diodes" by J. C. Henderson and Dr. J. R. Tillman at 5.30 at Savoy Place, W.C.2.

24th. Television Society.—Fleming Memorial Lecture—"Luminescence" by H. G. Jenkins (G.E.C.) at 7.0 at the Royal Institution, Albemarle Street, W.1. (Admission by ticket only.)

24th. Physical Society.—"Detection and measurement of vibration" by M. L. Parsey at 5.30 at Imperial College, Imperial Institute Road, South Kensington, S.W.7.

25th. R.S.G.B.—Presidential address followed by "Miniature aerials" by F. Charman (G6CJ), at 6.30 at the I.E.E., Savoy Place, W.C.2.

29th. I.E.E.—Discussion on "The performance of d.c. amplifiers with special reference to the use of transistors" opened by K. Kandiah and Dr. G. B. B. Chaplin at 5.30 at Savoy Place, W.C.2.

30th. Brit. I.R.E.—Battery operated equipment: "A.M.-F.M. receivers" by R. A. Lampitt and J. P. Hannifan; and "Radioactivity Instruments" by K. E. G. Perry at 6.30 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

ABERDEEN

9th. I.E.E.—"Colour television" by Dr. G. N. Patchett at 7.30 at the Caledonian Hotel.

CHELMSFORD

15th. I.E.E. (Students).—"Auto-following radar systems" by J. A. Barber at 7.0 at the Public Library.

DUBLIN

17th. I.E.E.—"The use of radio for communication links" by D. McKenna at 6.0 at the Physical Laboratory, Trinity College.

DUNDEE

10th. I.E.E.—"Colour television" by Dr. G. N. Patchett at 7.0 in the Electrical Engineering Department, Queen's College.

EDINBURGH

11th. Brit. I.R.E.—"Potted components and assemblies" by H. G. Manfield at 7.0 at the Department of Natural Philosophy, University of Edinburgh.

GLASGOW

17th. Brit. I.R.E.—"Industrial applications of high-speed pen recorders" by R. Kasler at 7.0 at the Institution of Engineers and Shipbuilders, 39 Elmbank Crescent.

HANLEY

18th. I.E.E.—"Digital computers" by Dr. S. H. Hollingdale; and "Power system engineering problems with reference to the use of digital-computers" by C. Robinson and D. H. Tompsett at 7.0 at Twyford Scout Hall.

LEEDS

22nd. I.E.E.—"Germanium and silicon power rectifiers" by T. H. Kinman, G. A. Carrick, R. G. Hibberd and A. J. Blundell at 6.30 at 1 Whitehall Road.

LIVERPOOL

2nd. Brit. I.R.E.—"Instrumentation for frequency modulation" by D. R. Willis and A. G. Wray at 7.0 at 1 Old Hall Street.

23rd. I.E.E.—"The electronic control of machine tools" by N. Milne at 6.0 at the Temple, Dale Street.

LLANDARCY

23rd. Society of Instrument Technology.—"Present and future trends in electronic instrumentation" by R. J. Redding at 7.0 at the Training Centre of the National Oil Refineries, Ltd.

MANCHESTER

3rd. Brit. I.R.E. and Junior Institution of Engineers.—"Projection television receivers" by I. Somers at 6.30 in the Reynolds Hall, College of Technology, Sackville Street.

11th. Institute of Physics.—"Ferromagnetism and magnetic materials" by A. E. De Barr at 6.45 at Bragg Building, Manchester University.

NEWCASTLE-ON-TYNE

21st. I.E.E.—"Electronics and automation: some industrial applications" by Dr. H. A. Thomas at 6.15 at King's College.

PORTSMOUTH

14th. I.E.E. (Students).—"Digital computers and how they may help the engineer" by Dr. M. V. Wilkes at 6.30 at the C.E.A., High Street.

TREFOREST

16th. Brit. I.R.E.—"Radio techniques in Post Office engineering" by C. T. Lamping at 6.30 at the Glamorgan Technical College.

WOLVERHAMPTON

9th. Brit. I.R.E.—"Design and application of magnetic amplifiers" by R. G. Russell-Bates at 7.15 at the Technical College, Wulfruna Street.

RANDOM RADIATIONS

By "DIALLIST"

Do We Want Colour?

A QUESTION one is pretty well certain to be asked during any conversation about television with non-technical folk is: *When* are we going to get colour TV? Or, the inquirer may put it in the more impatient form: When *are* we going to have colour TV? It was the same, one gathered, in the United States in the days when only the black-and-white picture was available. Everyone professed eagerness to have colour; but when it came along it was to prove just about the greatest flop in the history of American big business. Those who had seemed so ardently to desire it developed a sales resistance that even the most high-pressure salesmanship couldn't break down. Some months ago it was estimated that there were possibly 100,000 colour receivers in use in the whole length and breadth of the U.S.A.; but a recent investigation by an American magazine puts the total no higher than 75,000. It can hardly be the prices of such sets that have been the snag. These have been brought down from about $1,000 to the neighbourhood of $750 or so, and there must be plenty of Americans well able to afford that. One hears of coming models which are to be priced at $500 or less, but I doubt whether even they will get things really going.

Still Too Complicated

No, the trouble has been, and still is, that colour receivers are complicated boxes of tricks, needing constant adjustment. You can't just sit at your ease and watch. You've got to be continually jumping up from your chair to twiddle knobs for the colours to remain anything like right. Nobody wants exasperating "entertainment" of that sort, and I'm sure that if colour television using any system yet developed became a reality in this country it would flop here as monumentally as it has on the other side of the Atlantic. After all, the monochrome picture isn't all that unsatisfactory, or there wouldn't be well over 6,000,000 sets in use here, or some 34,000,000 (I think that's the figure) in the United States. I know I'd far rather have a good black-and-white picture and a set seldom needing anything but to be switched on and off than a coloured one (rather crude and garish at the best of times) produced by a set which called for constant attention. Them's my sentiments, anyhow; yours, of course, may be quite different.

Basic Inventions Needed

The present position of colour seems to me to be comparable with that of monochrome television when Baird had developed it as far as the scanning disc and neon lamp stage. That had little or no entertainment value and sales were small. For colour to be a success basic new inventions are needed. The flat c.r. tube with its "built-in" frame screen now being developed by Dr. Gabor may be one of these, if, as one hopes, it comes up to expectations when it reaches its final form. But others, too, are wanted if the colour receiver is ever to be as simple to operate as the monochrome and to be as suitable for use by the ordinary non-technical viewer. I've no doubt whatever that such inventions will be made; but when that'll be no one can say. Hence, no one can even attempt to answer the question: When are we going to have colour TV?

The Power of Suggestion

Talking of colour television reminds me that many people reported that they had seen colours on their black-and-white screens when the I.T.A. recently tried out a scheme of colour-by-suggestion. When I was last in London, shortly before this was written, two or three friends (whom I shouldn't have thought prone to imagining things) were in no doubt whatsoever that they had received pictures with distinct traces of colour while watching the B.B.C.'s experimental colour transmissions. Perhaps if the powers-that-be suggest hard enough that our present "penny plain" transmissions are really "tuppence coloured" there'll be no need to develop a genuine colour system!

V.H.F. Catching On

FROM what I hear in talks with people of all sorts and conditions, the v.h.f./f.m. broadcasting service seems to be gradually catching on, though it hasn't yet become as popular as it deserves. I don't think that quite enough publicity has been given to the freedom from interference and the silent background that can be given by a good v.h.f. receiver, provided that it's been properly installed. And I think it a pity that more manufacturers remain unconvinced that there's a big potential market for the press-button, or selector-switch set, pre-tuned to the Home, Light and Third Programmes. Nor, again, has sufficient prominence been given to the much superior quality obtainable. In these days, when Hi-Fi is all the rage, one would have thought that first-rate v.h.f. sets would sell like hot cakes. I'm all for omitting the long- and medium-wave ranges altogether; but, as the Editor pointed out a month or two ago, the public generally insists on being able to receive commercial transmissions from the Continent.

The Aerial Problem

Some folk, too, don't like the idea of adding yet another aerial to the not-very-beautiful arrays which already sprout from their roofs. Unless you're in a wireless shadow a simple dipole is all that is needed up to ranges of 45-50 miles at any rate. If your TV transmitter is vertically polarized such a dipole can often be fixed inconspicuously to the mast carrying the H, X, K or what not. In some areas where the television transmissions are horizontally polarized the one aerial array may serve perfectly well for both television and v.h.f. sound. I'm pretty sure that it will in the Norwich area, for instance; but I haven't yet been able to find out for certain, for at the time of writing we're still eagerly awaiting the *début* of Tacolneston as a v.h.f. broadcasting station. Another great help towards solving the aerial problem, at shortish ranges anyhow, may be the use of built-in ferrite rods.

A Spot of Bother

ONE doesn't envy the I.T.A. its job of trying to provide a good service in that TV spot of bother, the Sheffield area. Some parts of it lie in valleys; some are amongst the hills; many are heavily built up. But it's such a populous and important place that the I.T.A. must feel compelled to do everything possible to give it a satisfactory commercial service. The B.B.C. is more fortunate, for the site of Holme Moss is higher and its carriers lower than that of Emley Moor. Even so, there are many Channel 2 black spots in and around Sheffield. On Channel 10 things are much more difficult, for its carriers are so much more liable to be blanketed by hills or tall buildings and to suffer the reflections which give rise to ghosts. It may be that Emley Moor's aerial, 1,250ft above sea level, and its 200-kW e.r.p. won't provide all the answers, and the only thing for some districts will be a "piped" service.

UNBIASED

By FREE GRID

Microromeos

LOVE is a delicate subject which I had always thought to be completely outside the scope of this journal, but the impact of modern technology seems to have altered all that. Love seems well on the way to becoming merely a specialized branch of electronics, and will, I suppose, eventually be measured in microromeos or microcasanovas.

I have already referred to Dr. Grey Walter's recent pronouncement that it would be possible to pick out people who would make compatible marriage partners by examining their encephalograms.

Now we have Gerald Sykes speaking in the Third Programme on the subject of "Technology and Love." Mr. Sykes is an American and therefore would probably be more familiar with wolf whistles than with heterodyne whistles. It appears that, according to Mr. Sykes, to understand what love is we need to study the psychology of Freud and Jung, and this leads us rather away from electronics into the jungle of the "id" and the "superego."

But we are brought sharply back to the electronic fold by the latest suggestion that the electronic computer can solve all problems of love and lead to happy marriages. Apparently all that is needed is to feed into a computer the necessary data about any budding Benedick and his Beatrice and it will decide whether or not they are suited to each other.

I don't think it will be nearly so simple as it is made out to be, for such a lot will depend on the experts who have to decide what is the proper data the computer needs before it can make its calculations. Having decided on the data, the experts then have to turn it into the special binary lingo of the ACE. Personally I would far sooner trust the old-fashioned "Aunty Gertie" who solves love's problems in certain of the more romantic of our women's magazines.

I sincerely hope the day is far distant when *W.W.* publishes some book like "Second Thoughts on Love Theory," by "Cathode Ray."

Fiat Justitia

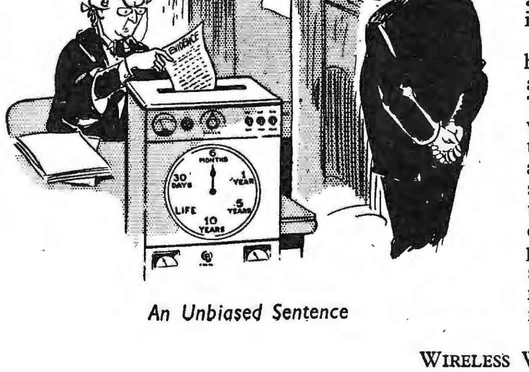
WE hear of such extraordinary things being accomplished by electronic computers that it surprises me that more attention has not been paid to them by the medical profession.

Surely a machine could be designed which, when fed with the requisite numerical data concerning bodily temperature, blood pressure and so on, could make a swift calculation and diagnose the complaint. At the same time it might indicate the correct antidote.

Without doubt such a machine is a possibility of the future and I am very surprised that this doesn't seem to be realized in medical circles. Maybe it is because doctors have a vested interest in keeping any form of mechanical medico off the market. Doctors would, however, always be wanted to feed accurate data to the machine.

Another class of person which has neglected its possibilities is represented by the various Mesdames Estelles who haunt our seaside piers and funfairs. An electronic prognosticator would not put them out of business. They would still be wanted to feed all the enquirer's personal details to the machine to enable it to work out the positions of the planets and other heavenly bodies at the precise moment of birth.

A most important potential field of operations for the computer is surely in our magisterial courts. We often read of the great divergence in the penalties imposed by different benches for the same offence. A wife beater, for instance, who is arraigned before a bench of hard-bitten married men may incur little more than a mild "tut-tut" of reproof from the long-suffering chairman. If, however, he has the ill-luck to appear before a women stipendiary or a bench on which women predominate he can thank his lucky stars that the death penalty is *ultra vires* for magistrates. An electronic computer when fed with the correct data on the crime and the prisoner's previous record would unerringly deliver a just and equitable sentence.



An Unbiased Sentence

TV on Trains

I WAS interested to read recently of the television demonstration given on two specially equipped excursion trains in Scotland. The programmes in each case came from the Guard's van which had been turned into a small studio. No attempt was made to relay ordinary broadcast TV programmes but the demonstration was none-the-less interesting as showing what we can expect in a few years' time.

It would not surprise me if TV eventually became available on all long-distance trains. Would it be possible to use the adjacent telegraph wires for a carrier-current system? It would, of course, be rather like putting the cart before the horse to have TV on trains, as no serious attempt has yet been made in this country to provide ordinary sound programmes in our expresses; yet it has always seemed to me that it would be so easy to provide each passenger who wanted this service with a pair of headphones at an appropriate fee. A start could be made by having a disc jockey in the guard's van of each train; real radio could come later.

Another thing which is lacking in our trains, despite the electronic age in which we live, is means of making a telephone call. There has not even been an attempt to provide a *telegraphic* service, and personally I have been compelled to follow the example of castaways on a desert island and enclose a message in a beer bottle obtained from the restaurant car. This I have had to throw out when passing through a station in the hope that some porter might pick it up, and usually I have not hoped in vain.

The method is, however, primitive and I hope that this TV demonstration will open the eyes of the British Railways' authorities to the possibilities of equipping trains with an up-to-date telegraph, telephone and television service. The profits might enable them to reduce fares.