Wireless World

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Television Complications

BRITISH television, in its original form, grew up pretty much according to plan and, in technical matters at least, the situation was always fairly well in hand. But subsequent developments, and particularly the incursion into another frequency band, have shown that it is almost beyond the powers of human foresight to envisage all the possibilities of trouble. That is why we are glad to see that the B.B.C. experimental transmissions in colour, which began on October 10th, were embarked upon with due caution and with no suggestion that the system used will be chosen for a regular service. According to the Corporation's statement, the so-called British N.T.S.C. system "*might* prove suitable" (our italics).

The British Radio Equipment Manufacturers' Association, in welcoming the start of the colour experiments, showed equal caution, and expressed the view that at least two years would elapse before any decision could be made.

Naturally enough, the industry is anxious that the general public should not be under the mistaken impression that colour television is likely to start in the immediate future. There is every reason, however, why the problems of colour should, in the meanwhile, be freely discussed in technical circles. Indeed, that applies to all aspects of television, and we sometimes think the official mind is unduly shy of the limelight.

An example of what seems to be unnecessary reticence has arisen over the transmission characteristics of the new London station at the Crystal Palace. A B.B.C. statement has just been issued saying that it is to work on the vestigial sideband method on vision, with the upper sideband partially suppressed; the present Alexandra Palace station works on double sideband. This change was generally expected and, indeed, was foreshadowed in *Wireless World* a couple of years ago; why the delay in making the announcement?

Another of the unexpected difficulties of television has come to light in connection with t.r.f. receivers, some of which will be rendered obsolete by the change mentioned in the last paragraph. As described in an article on p. 526, the use of these receivers, in conjunction with a Band III convertor, has been found to produce serious interference with nearby receivers tuned to Band I. Though we have published warnings against various difficulties in the use of convertors, we must admit to having overlooked this particular trouble.

Gallons Into Quart Pots

WE are constantly being reminded that the world's supplies of such vital commodities as coal and oil are running low. But complete exhaustion of our resources is never quite in sight, and, if and when the worst happens, nuclear energy is confidently expected partly at least to make good the deficiency.

Not so with the radio communication spectrum, in which there are no rich seams yet undiscovered and no new "gushers" waiting to be tapped. The full extent of our national resources is known precisely; these resources are inelastic and all that can be done is to use the communication channels we have to the best effect.

One method, which is of great practical significance at present, is to reduce the channel width. Many allocations were made on what now seems to be an unnecessarily lavish basis. A case in point is that of the mobile radio-telephone service, for which the channel width as at present allocated is 100 kc/s. The possibility of reducing this to 50 kc/s was considered in a report made to the Postmaster-General some months ago, but no decision was reached. Now, as reported on p. 527, a demonstration has been given of interference-free working in adjacent channels only 25 kc/s wide—an achievement twice as great as the proverbial one of getting a quart into a pint pot.

This excellent example of channel conservation has been brought about by the extension of straightforward and well-tried methods, and so there seems to be no technical reason why 25-kc/s channels should not be generally adopted in the mobile service, for which there is an acute shortage of space. The difficulties appear to be mainly economic, though it is understood the new 25-kc/s equipment is not significantly more costly.

Interference from Band-III Convertors

By F. HOWARD STEELE

Radiation on 45 Mc/s

THE advent of television broadcasting in Band III appears to add yet another source of interference to the B.B.C. transmissions in Band I. The trouble arises from Band-I t.r.f. set owners who have converted their sets to receive Band-III transmissions by adding one of the popular "universal" convertors to the front end of their receivers. These convertors usually consist of an r.f. stage followed by an oscillator/mixer, the oscillator being tuned so that the convertor output frequency is the same as the local B.B.C. transmission in Band I.

This I.T.A.-modulated Band-I signal is then amplified through the t.r.f. stages of the receiver until in the region of the detector a signal of several volts in amplitude is obtained. Unless the screening of the receiver is unusually efficient, a few millivolts of this I.T.A.-modulated Band-I signal is picked up by either the Band-I or Band-III aerial leads and is re-radiated. Because of local oscillator drift in the Band-III convertor this radiated signal is not of constant frequency, and variable frequency beats are produced with the B.B.C.'s Band-I transmissions.

The effect on the screen of television receivers operating on Band I anywhere within 100 yards or so of the offending "viewer" is extremely irritating. A vicious herring-bone pattern appears on the screen which is constantly on the move, starting first one way and then the other as the re-radiated signal drifts above and below the frequency of the local B.B.C. transmission in Band I.

Additional Complications

The cause of this interference would seem difficult enough to cure as it is, without two more contributory factors which make it well nigh impossible. The first of these additional complications is the number of t.r.f. receivers which are of the a.c./d.c. type and therefore cannot be properly earthed. The second is the current practice of using unbalanced coaxial cable as the downlead from an aerial which is inherently a balanced device. This prevents one from considering the downlead as a simple transmission line.

The last-mentioned complication can be remedied, of course, by fitting a balance-to-unbalance transformer at the aerial end of the downlead, but if this is done without careful thought impedance matching problems arise. Theoretically, if correct matching is to be obtained, one should use a quarter-wave line transformer between the end of the feeder and the upper element of the dipole and a three-quarter wavelength line between the end of the feeder and the lower element of the dipole. Apart from the complication of so doing, however, it would tend to make the collection of scrap iron we have on our chimneys these days look even more untidy than it does at present.

Should any readers consider doing this, however, it should be remembered that the mechanical length of a piece of coaxial 75-ohm feeder is shorter than its electrical length, because of the slower propagation rate in this type of cable. The transmission factor of ¼in solid Polythene insulated coaxial is approximately 0.66 and the matching stubs should be shorter than the equivalent free-space wavelength by this factor.

The problem of providing a satisfactory r.f. earth at the receiver input terminals is more difficult. In theory the length of the earth wire should be a multiple of $\lambda/2$ where λ = wavelength of local B.B.C. transmission in Band I. In practice, it would appear impossible to calculate this length, due to the indeterminate stray capacitances to the surroundings of this earth wire and the difficulty of knowing exactly where "earth" is at the far end. A semi-practical solution is to insert a series LC circuit in the earth lead and by varying the L or the C attempt to tune the earth wire to an exact half wavelength. If this can be done (and so far the author has failed to do so) then the receiver input will be at r.f. earth potential so far as the Band-I transmission is concerned and, in conjunction with a balance-to-unbalance modification to the aerial system, one will be well on the way to solving the re-radiation problem.

Having stopped the t.r.f. receiver "bouncing up and down at the end of its earth wire" at I.T.A.-modulated Band-I frequency, the next problem is how to stop the spurious Band-I radiation from the t.r.f. receiver being passed back up the aerial feeders and being re-radiated by either the Band-I or Band-III aerials.

Considering the Band-III aerial first, the solution in theory is not too difficult. All that is required is a high-pass filter to be fitted in the aerial feeder as far away from the t.r.f. receiver as possible. This filter should look like 75 ohms when viewed from either the aerial or the receiver if a mis-match is not to occur and it should ideally have zero insertion loss at Band-III frequencies and an infinite insertion loss at Band-I frequencies. In practice a simple π-type filter with a capacitor as the series element appears to work reasonably well, but the calculated values of inductance in the shunt arms are so small as to make their construction largely a matter of trial and error. (To obtain the required 0.148μH one or two turns, ¼in diameter air-spaced, are necessary.) In addition, the two inductors need to be separated by an earthed screen (through which the series capacitor, about 12pF, passes) to avoid mutual coupling between them. The whole filter is then placed inside a fully screened box. Such a filter has a designed cut-off frequency of approximately 90 Mc/s and a characteristic impedance of 75 ohms—we hope!

In practice such a filter makes a substantial reduction in the level of radiated interference but is not in itself a complete cure by any means. One is still not on speaking terms with one's immediate neighbours

Stopping the Band-I aerial re-radiating is more difficult, and so far no satisfactory cure has been found. One cannot put a high-pass filter or even a band-stop filter in this downlead because, being a two-way device, it precludes the possibility of observing the Old Lady of Shepherd's Bush when one wants to.

Some Band-III convertors on the market short-circuit the Band-I aerial when it is not in use, but this discontinuity, of course, tends to set up standing waves in the Band-I aerial feeder with consequent radiation. A better solution would appear to be terminating the unused aerial feeder in 75 ohms and screening the termination.

It will be gathered from the above that the author owns a t.r.f. receiver and a Band-III convertor of the type referred to. Both the receiver and the convertor are fully screened and yet he must confess, however unknowingly at the time, to causing Band-I interference on the opening night of the I.T.A. transmissions—a fact which a kind but suspicious neighbour was not slow to suggest the following day. Since that time considerable thought has gone into ways and means of suppressing this interference, which in the author's location appears to be a very real problem. A considerable reduction in the level of interference has resulted, but the interference pattern is still visible on receivers up to 100 yards away.

The only foolproof solution would appear to be the conversion of the t.r.f. receiver to a superhet, using a commercial turret tuner as a front end and dropping the existing 45-Mc/s r.f. strip down to the new preferred British i.f. of 34.65 Mc/s. As the oscillator in such tuners is usually above the Band-I frequency (to avoid harmonic breakthrough) this inverts the relative position of the sound and vision channels and the sound i.f. comes out at 38.15 Mc/s. This, fortunately, is within the range of adjustment of the majority of existing sound receiver circuits and no modification is necessary.

Pending this rather drastic step, the author has not dared to tune in to the I.T.A., and is all the more infuriated to find that others are now causing exactly the same interference as he did on the opening night. It is small consolation to be able to show suspicious neighbours who "just drop in for a chat" that he, too, is suffering the same interference as they are.

Unless anyone can suggest a lasting, immediate and hundred-per-cent effective cure, it is up to all owners of t.r.f. receivers plus convertors to check without delay whether they are radiating this interference. Moreover, radio dealers should be discouraged from selling these Band-III convertors to any t.r.f. set owner unless he has checked that no interference will result. To have bought a convertor, to have sniffed the rabbit (however young and immature) and not to be able to watch his progress is almost intolerable, and yet it seems the only way if one is to remain at peace with those who live nearby.

Narrower Mobile Radio Channels

BAND III is now in the process of being cleared for television purposes and when the job is completed the space left for private mobile radio users will be only about 7 Mc/s. This imposes a severe restriction on the development of mobile radio which can only be overcome by reducing channel widths. An official body has already recommended that the present 100-kc/s channel width should be reduced to 50 kc/s* but it now seems that the belt can be tightened even more. Pye Telecommunications have recently demonstrated a new two-way mobile radiotelephone, known as the "Ranger," designed for channels as narrow as 25 kc/s. This, of course, makes possible four channels in the space occupied by one at present.

With such close spacing the problem of cross-talk between channels becomes really acute, and it is essential that good frequency stability shall be maintained in the equipment. The Pye transmitters and receivers are crystal-controlled, of course, and the crystals themselves are cut in a manner which gives high stability operation (AT-cut crystals). The transmitter consists of an oscillator followed by three frequency multipliers and a power amplifier, with a modulator comprising a phase splitter and push-pull output stage. An r.f. output power of 4-6 watts is obtained and the frequency drift is claimed to be less than $\pm 0.002\%$. The receiver is a double superheterodyne with two crystals and eleven valves and is provided with noise-limiting and a.g.c. circuits. Sensitivity is $1 \mu V$ for 100mW output, while the frequency drift here is claimed to be less than $\pm 0.0025\%$.

The equipment will work anywhere in the frequency range 25-174 Mc/s on either single- or double-frequency simplex, and is operated by a "press-to-talk" switch on the hand microphone. Transmitter, receiver and power supply are housed in a steel case intended for fitting under the dashboard of a motor vehicle, as shown in the photograph below.

In the demonstration of the equipment, four mobile units in motor vehicles were receiving from four 15-watt fixed transmitters in adjacent 25-kc/s channels (actually 161.725, 161.75, 161.775 and 161.8 Mc/s), the mobile transmitters and corresponding fixed receivers being spaced from these by 4.5 Mc/s (at 157.225, 157.25, 157.275 and 157.3 Mc/s respectively). In spite of this close spacing there appeared to be no cross-talk between channels except a slight trace when the mobile units had been driven very close to the fixed transmitter aerials.

* "Report of the Mobile Radio Committee," H.M.S.O., price 9d; summarized in "Mobile Radio," *Wireless World*, May, 1955.

WORLD OF WIRELESS

British N.T.S.C. Tests ✦ H.P. and Retail Sales ✦ Engineering Opportunities

Colour Television Tests

THE promised television test transmissions in colour began from Alexandra Palace on October 10th. The system being used in these initial tests, which are being radiated outside normal programme hours, is the British adaptation of the American N.T.S.C. system (see our August issue). Other systems may be tried later on.

These tests, which are being carried out in agreement with the Television Advisory Committee, are mainly to ascertain whether a truly compatible system should be the final objective. Viewers in the London area will have the opportunity of finding out if there is any appreciable degradation of the monochrome picture.

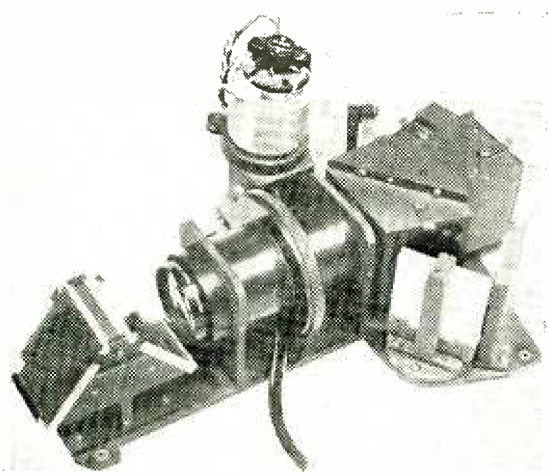
New Television Stations

TWO new television stations, both operating in Channel 4 (61.75 Mc/s vision and 58.25 Mc/s sound) have been brought into service by the B.B.C. during the past month.

The first, a 1-kW temporary Channel Islands transmitter at Les Platons, Jersey, at present has to rely on the reception of transmissions from the temporary station at North Hessary Tor. The permanent Devon station will be in use early next year. The signals are picked up at a receiving station at Torteval, Guernsey, and conveyed to Jersey by a radio link.

The other new station is the permanent transmitter at Meldrum, 20 miles north-west of Aberdeen. It has an e.r.p. of 12 kW and replaces the temporary transmitter at Redmoss, which has been in use for the past 12 months.

Both stations use horizontal polarization.



OPTICAL ASSEMBLY of the three-tube colour camera which, with its associated equipment, has been supplied by Marconi's for the B.B.C. colour television tests. The film and slide-scanning equipment being used in the tests was developed and built by the B.B.C. Research Department.

Rear-Admiral K. H. T. Peard speaking at the farewell dinner to Rear-Admiral Sir Philip Clarke whom he succeeds as director of the naval electrical department. Sir Philip has been nominated for a second year as president of the Brit. I.R.E.

Retail Sales

THE increase in the hire-purchase deposit on broadcast receivers introduced at the end of July is reflected in the survey of retail sales during August, prepared by the British Radio Equipment Manufacturers' Association. It will be seen from the table, in which the hire-purchase sales are given as a percentage of the total sales for each of the past six months (they are not available for January and February), that the proportion of credit transactions has dropped considerably.

	Sound	Radiograms	Television
January ...	98,000	35,000	103,000
February ...	99,000	33,000	98,000
March ...	95,000 (41%)	24,000 (62%)	85,000 (59%)
April ...	79,000 (42%)	16,000 (63%)	75,000 (59%)
May ...	75,000 (43%)	15,000 (68%)	62,000 (59%)
June ...	74,000 (40%)	13,000 (67%)	58,000 (57%)
July ...	84,000 (41%)	13,000 (67%)	61,000 (61%)
August ...	73,000 (33%)	11,000 (54%)	64,000 (53%)
	677,000	160,000	606,000

Engineers in the B.B.C.

OPPORTUNITIES for graduate engineers and physicists in the B.B.C. are outlined in a booklet "Engineers in the B.B.C." Of the 4,500 employed in the engineering division, 600 are fully qualified engineers and physicists and about 2,300 "engineers who may not necessarily be fully qualified academically" who are mainly employed on operations and maintenance.

Each year the B.B.C. offers a number of two-year apprenticeships to graduate engineers and physicists who obtain Honours degrees. The course includes a period of training at the B.B.C. Engineering Training Department at Evesham, six months' practical works training in industry and some months in two or more of the specialist departments of the B.B.C.

The booklet can be obtained from the Engineering Establishment Officer, B.B.C., London, W.1.

Welsh V.H.F. Service

PENDING the construction of permanent v.h.f. stations in North Wales, a temporary v.h.f. transmitter has been installed at the Penmon, Anglesey, medium-wave station and was brought into service on October 2nd. The transmitter, which is horizontally polarized, radiates the Welsh Home Service on 94 Mc/s with a power of about 1 kW. The station will eventually have three transmitters—one for each programme.

V.h.f. transmitters are already being installed at Wenvoe, Glam., which is is hoped to bring into service by the end of this year.

PERSONALITIES

F. S. Barton, M.A., B.Sc., F.Inst.P., M.I.E.E., has left the Ministry of Supply, where he has been since 1946 (latterly as principal director of electronics research and development), to become defence supply adviser to the High Commissioner in Ottawa. In 1922 he joined the radio department of the Royal Aircraft Establishment, Farnborough, of which he became deputy head in 1936, and from 1941 to 1946 he was director of radio engineering with the British Air Commission in Washington. His father, Professor E. H. Barton, F.R.S., D.Sc., was a pupil of Hertz in Bonn.

F. S. BARTON.

D. H. Black, M.Sc., Ph.D., F.Inst.P., who has been in the Civil Service since 1939, succeeds Mr. Barton as principal director of electronics research and development at the Ministry of Supply. For two years from 1943 he was on loan to the Admiralty after which he spent two years at R.R.D.E. (now R.R.E.), Malvern, before being appointed director of electronics research and development (defence) at the M.o.S., a post which he held until 1953 when he went to Australia as head of the United Kingdom Ministry of Supply staff in the Commonwealth. Before joining the Civil Service he was 14 years in industry, spending the last seven with Standard Telephones and Cables. Dr. Black, who is 56, is succeeded in Australia by Dr. W. H. Wheeler.

Dr. A. H. M. Arnold is leaving the National Physical Laboratory, where he has been head of the electronics section of the electricity division, to become reader in electrical engineering at King's College, London. Dr. Arnold, who in 1923 graduated from Liverpool University from which he received the degrees of Ph.D. and D.Eng., spent a year at Metropolitan-Vickers before going to the N.P.L. in 1926. He is 54.

F. H. Townsend, M.I.E.E., director and general manager of Cathodeon, Limited, Cambridge, was elected vice-president of the British Amateur Television Club at the second Amateur Television Convention recently held in London. Mr. Townsend joined the Pye Group seventeen years ago and has been with Cathodeon (a member of the Group) since its formation during the war.

J. D. Parker, B.Sc.(Hons.), is the new secretary-general of the Comité International Radio-Maritime, of which H. C. Van de Velde is president. Colonel Parker, who is on the Regular Army Reserve of Officers, was in Royal Signals during the war and from 1941 to 1945 was in charge of the planning and technical section of the inter-services research bureau. After the war he joined the Control Commission in Germany as controller of radio. Before being called up in 1939 he was in the G.P.O.

W. A. Roberts, A.M.I.E.E., has been appointed regional engineer (Midland Region) by the B.B.C. in succession to **J. A. Cooper,** B.Sc.(Eng.), A.M.I.E.E., who is retiring after 32 years' service with the Corporation. Mr. Roberts, who joined the engineering division of the Corporation in 1937, became assistant to the chief engineer in 1949. Two years ago he was seconded to the Colonial Office as technical adviser on broadcasting development in the Colonies and was a member of the Commissions appointed to study broadcasting in the Gold Coast and Kenya. He returned to the B.B.C. a few months ago. Mr. Cooper, who has held his present position since 1950, was previously engineer-in-charge at Birmingham.

Michael Cooper, B.Sc., Grad.Inst.P., has been appointed planning engineer for teleciné and telerecording by Granada TV Network, Limited, the Monday-to-Friday programme contractors for the I.T.A. Lancashire station. He had been with the B.B.C. since 1951 where he was concerned with the planning and installation of studio and teleciné equipment. He was previously with Pye (1945 to 1946) and the G.E.C. Research Laboratories (1946 to 1951).

Granada TV Network, Limited, have also appointed **John C. McKenzie,** B.Sc., as television engineer for studio planning. In 1952, on leaving the University of Southampton where he obtained his degree, he was appointed research engineer at E.M.I. Research Laboratories where he was engaged on the initial experiments with the completely stabilized c.p.s. Emitron camera tube. For the past year he has been in the B.B.C. planning and installation department.

W. C. Pafford, who is both a television engineer and a lighting engineer, has left the B.B.C. after 23 years' service to join the Associated Broadcasting Company (now Associated Television, Ltd.), programme contractors for the London (week-ends) and Midland (week-days) I.T.A stations. He became a maintenance engineer at Alexandra Palace in 1936 and was later in charge of maintenance and war-time operations at the station.

L. E. C. Hughes, Ph.D., M.I.E.E., who was for some years with Londex, Limited, has recently been appointed head of the technical publications department of Ultra Electric, Limited. We understand that he is compiling a reference book on electronics applied to industry.

Walter Titmus, Assoc.Brit.I.R.E., has taken charge of the recently formed industrial controls division of the Solartron Electronic Group, Limited, which he joined in June after six years with Plessey's. From 1929 to 1938 he was with the Marconi International Marine Communications Company. In 1938 he joined the Army, becoming Captain (R.E.M.E.) in charge of the First Airborne Division's mobile and base radio workshops. From 1945 until he joined Plessey's in 1949 he was with E. K. Cole.

H. S. Payman, B.Sc., M.I.E.E., has been appointed general manager of Suflex, Limited, who are now manufacturing polystyrene capacitors in addition to their normal range of sleeving, wire and braided products. He was previously deputy director of component production and general manager of A.B. Metal Products.

F. Szekely, B.Sc.(Eng.), Grad.I.E.E., formerly on the staff of the B.T-H. Co., has joined the radio division of the Edison Swan Electric Co., Ltd., to promote the application of semi-conductors. After completing his graduate apprenticeship with B.T-H. he went into the research laboratory.

OUR AUTHORS

S. E. Gent, who, with **D. J. S. Westwood,** writes in this issue on vision a.g.c., has been with Ferguson Radio for seven years and for the past two years has been in charge of one of the Company's television laboratories. He was previously with Peto Scott where, during the war, he was working on military projects and subsequently on domestic radio equipment. He graduated from the Northampton Polytechnic in 1949. Mr. Westwood joined Ferguson in 1953, having previously been with Cossor. He obtained his engineering degree in 1949.

W. Woods-Hill, author of "Electronic Digital Computors," is manager of research and development in the Calculator Research Laboratory of the British Tabulating Machine Co., Ltd. During the war he spent several years in radio and radar development units of the R.A.F., and subsequently became liaison officer attached to the French Air Force during the installation of their radar school at Auxerre, Yonne. He operates an amateur transmitter with the call G4JV.

A. L. P. Milwright, who describes a new microwave course beacon in this issue, is a principal scientific officer in the Royal Naval Scientific Service. He is at the Admiralty Signal and Radar Establishment, Portsmouth, and is in charge of the group which carries out development on civil marine navigational aids for the Ministry of Transport and Civil Aviation.

IN BRIEF

Receiving Licences.—An increase of 60,832 television licences during August brought the total in force in the United Kingdom at the end of the month to 4,786,415. These, together with the 283,473 for sets fitted in cars and the 9,054,699 for sound only, made an overall total of 14,124,587.

Vice-Admiral Dorling, director of the Radio Industry Council, will open this year's **Amateur Radio Exhibition,** organized by the Radio Society of Great Britain, at 12 noon on November 23rd, at the Royal Hotel, Woburn Place, London, W.C.1. It will close on the 26th.

R.S.G.B. News Service.—British amateurs now have an official broadcast news bulletin which is radiated on a frequency around 3,600 kc/s on Sunday mornings from 11.0 to 11.20 G.M.T. The bulletin is broadcast first on R/T, then keyed in abridged form and repeated on R/T. The station, call GB2RS, is operated at Walton-on-Thames, Surrey, by F. Hicks-Arnold (G6MB).

Science and Management.—The programme of the National Conference of the British Institute of Management, which will be held at Harrogate on November 2nd to 4th, includes a number of papers of interest to electronics engineers. Dr. B. V. Bowden, principal of the College of Technology, Manchester, will speak on electronic processing of data for management and John Diebold (U.S.A.) will deal with automation. Details of the Conference, the theme of which is "The impact of science on management in the future," are obtainable from the Institute, Management House, 8, Hill Street, London, W.1.

The 100 papers (ranging from transistors to transducers and communication theory to circuit design) presented at the 11th **National Electronics Conference** held in Chicago at the beginning of October will be published in volume 11 of "Proceedings of the National Electronics Conference." It will be available early next year, price $5 from 84, East Randolph Street, Chicago 1, Illinois.

A steady growth in the membership of the **Tensor Club of Great Britain** during its first five years is recorded in the report sent to us by the joint organizers, Dr. W. J. Gibbs and S. A. Stigant. It now has a membership of 137 with over 50 per cent outside the U.K. Gabriel Kron, of America, an authority on tensor analysis, is patron of the club and during a recent visit to this country gave a series of lectures on the subject in London. Details of the club are obtainable from S. A. Stigant, 7, Courtlands Avenue, Hayes, Kent.

The annual dinner of the **Telecommunication Engineering and Manufacturing Association,** of which H. Faulkner is director, will be held at the May Fair Hotel, Berkeley Street, London, W.1, on November 10th. The Association is concerned mainly with general policy matters in the telecommunication manufacturing industry.

Television Test Signals.—At any time between 10 a.m. and 11 p.m. (Monday to Friday) or 9.30 a.m. to 11 p.m. (Saturday) when programmes are not being radiated from the I.T.A. Croydon transmitter, a test signal on full power is now transmitted. No test signals are radiated on Sunday. The B.B.C. test period is from 10 a.m. to 1 p.m. (Monday to Saturday) and for the usual few minutes before the opening of each programme. The times of the test transmissions from the Belling & Lee transmitter (G9AED) at the I.T.A. site at Lichfield have been modified slightly. They are now 10 a.m. to 1 p.m., 3.0 to 6.0, and 7.30 to 8.30 (Monday to Friday) and 10 a.m. to 1 p.m. Saturday.

R.I.C. Dinner.—Sir Walter Monckton, Q.C., Minister of Labour and National Service, is to be the guest of honour at the annual dinner of the Radio Industry Council at the Dorchester Hotel, Park Lane, London, W.1, on November 23rd.

The Second Congress of the **International Commission on Acoustics** will be held from June 17th to 24th, 1956, in Cambridge, Massachusetts, in conjunction with the fifty-first meeting of the Acoustical Society of America. The secretary of the Congress is John A. Kessler, Acoustics Laboratory, Massachusetts Institute of Technology, Cambridge 39, Mass., U.S.A.

Films on Loan.—Two more electronics films have been added to the list of those available on free loan from the Central Film Library of the Central Office of Information. They are "Ultrasonics" (20 minutes) and "Manufacture of radio valves" (26 minutes), both produced by Mullard. Particulars are obtainable from the Central Film Library, Government Building, Bromyard Avenue, Acton, London, W.3.

Demonstrations of **Closed-Circuit Television** are being given by a team of R.C.A. engineers at three international trade fairs being held in the Far East during the closing months of this year. The fairs are in India, Indonesia and Pakistan.

Electron Telescope.—With the object of showing the possible application of electronics to astronomical observations Pye fitted television equipment to the telescopes at Dublin Observatory and gave demonstrations to delegates attending the ninth general assembly of the International Astronomical Union held in the city in September. The meetings were attended by 500 delegates from 34 countries.

A course of six lectures on **Magnetic Amplifiers** is to be held on Wednesdays at 7.0 at the Technical College, Bradford, commencing on October 19th. (Fee 30s.)

Interference from Television Receivers.—A decree laying down the permitted limits of interference from television receivers in the broadcasting bands between 150 kc/s and 30 Mc/s was recently made in France.

A new 20-kW short-wave broadcasting station has been brought into service by the **Tanganyika Broadcasting Service.** It replaces an ex-Army 250-watt transmitter which has been in use since 1951. The transmitter, studio equipment and aerial system were supplied by Marconi's.

"Long-Range Television Reception."—In this article in the October issue, the heading for two of the screen pictures on p. 505 was unfortunately lost in the course of printing. It should have been **Switzerland.**

Since the Classified Advertisements pages were passed for press, it has been found that an incorrect advertisement for **Shirley Laboratories, Limited,** appears on page 159. The correct prices for the equipment are those given in Shirley's first advertisement under "New receivers and amplifiers."

The transmitting equipment for the **I.T.A. Midland Station** is being supplied *by* Pye and not *to*, as stated in the note on page 496 of our last issue.

Since the publication eighteen months ago of the U.N.E.S.C.O. book **"Television: A World Survey,"** there has been a large increase in the number of television stations in operation and many more countries have made known their plans for the future. A supplement to this international survey has therefore been published (H.M.S.O. 3s.) bringing up to date the information on the television service in 58 countries and non-self-governing territories.

The annual **Electrical Industries Ball** in aid of the funds of the Electrical Industries Benevolent Association will be held at Grosvenor House, Park Lane, London, W.1, on November 11th. Tickets, price 2½ guineas, are obtainable from the E.I.B.A., 32, Old Burlington Street, London, W.1.

The first three **Scholarship Awards,** under the scheme announced a few months ago, have been awarded by the General Electric Company. These scholarships are to be awarded annually to selected members of the G.E.C. staff and provide for degree courses, post-graduate research or specialized studies.

BUSINESS NOTES

A contributing factor in the recent successful trials of the **Pye** underwater television camera on Lake Zurich, Switzerland, was the combined lifting rope and cable produced by **B. I. Callender's Cables.** It is a double-plastic-sheathed version of a standard polythene-insulated television camera cable with a hemp covering; overall diameter is 1¼in. By using this combined cable the time for lowering the camera, which weighs 2½cwt, was reduced from 45 to two minutes.

Lecture demonstrations of high-quality sound reproduction have been given by **Goodmans Industries, Limited,** in some fifty towns throughout the country during this year. The next and probably the last town to be visited in the present series is Luton, where, on November 15th and 16th, a demonstration will be given at 8.0 p.m. in the Town Hall. Tickets are obtainable from S. Farmer and Company, of Luton.

In the report on the S.B.A.C. Exhibition in our last issue we referred, on page 492, to the **Burndept** u.h.f. aircraft receiver (Type BE.234) as employing a frequency multiplication of 12 to obtain the spot operating frequency. The multiplication figure should have been six.

"Carcinotron."—Our attention has been called to the fact that the word "Carcinotron," used in our June issue as a general term to describe backward-wave oscillator valves, is the registered trade mark of the Compagnie Générale de Télégraphie sans Fil.

The installation of Pye v.h.f. radio-telephone equipment in the vessels of two more Thames lighterage companies brings the total number of users of this equipment on the London river to 32 companies operating over 300 sets. **Pye Marine** have also recently installed a station at the Dock Master's office in the port of Aberdeen and equipment in a pilot cutter and a dredger operated from the port.

The air traffic control and communications equipment at the re-opened Lympne Airport, Kent, is being provided by **International Aeradio, Limited.**

A mobile radio-telephone-equipped office has been put into service by the Automobile Association. Constructed by **British Films, Ltd.,** of Balham, London, on an articulated semi-trailer, it is equipped with Pye R/T gear. A feature of the unit is the hydraulic 60-foot telescopic aerial mast built into the rear of the vehicle.

Radio communication equipment and radar navigational aids have been ordered from **Marconi's** by Shell Tankers, Limited, for eight tankers now being built. Marconi's have also recently provided radio and radar gear for new trawlers for Fleetwood and Grimsby.

The sales and order departments of **McMichael Radio, Limited,** are now at Wexham Road, Slough, Bucks. (Tel.: Slough 24541).

Taylor Electrical Instruments, Limited, of 419/424, Montrose Avenue, Slough, Bucks, are offering service technicians allowances varying from £2 5s to £10 5s on Taylor instruments (up to about 14 years old and in working order) taken in part exchange for one of their latest models. The reconditioned models will be offered at a very low price to amateurs and students.

Ex-Government anti-aircraft radar mounted on trailers (Type AA3, Mark II) have been reconditioned by **Winston Electronics, Limited,** of Shepperton, Middx, for Government meteorological work, especially in the tropics. The reconditioning includes the substitution of a spark-gap modulator for the thyratron system.

E.A.P. (Tape Recorders), Limited, have moved from 546, Kingsland Road, London, E.8, to larger factory premises at 9, Field Place, St. John Street, London, E.C.1 (Tel.: Terminus 9627).

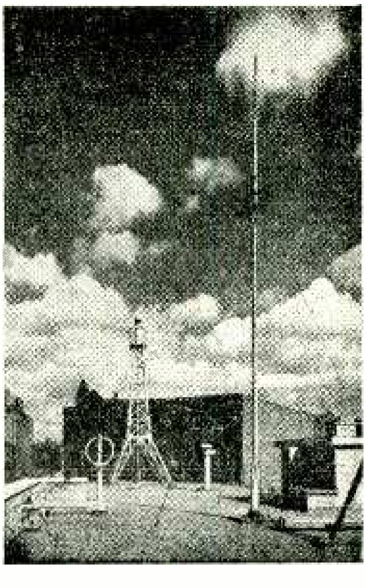
OVERSEAS TRADE

Canada.—A million-dollar contract for the construction of a mobile flight and tactical simulator to familiarize aircrews of the Royal Canadian Navy with the Grumman S2F anti-submarine aircraft, has been placed with Redifon, Limited. It combines facilities for flight familiarization with training in the use of radar and tactical anti-submarine equipment.

Component Exports.—According to figures issued by the Radio and Electronic Component Manufacturers' Federation, one-half of the present output of component manufacturers in this country, who now turn out about four million parts each working day, is exported either direct or assembled in equipment.

Thirty-one manufacturers of components and accessories participated in the joint exhibit organized by the R.E.C.M.F. at the **British Exhibition in Copenhagen,** which closed on October 16th after an 18-day run. In addition to the combined component display (the stands for which occupied a floor space of 1,300 square feet) Ekco and Mullard had individual stands. So far this year, exports of components to Denmark are well below the figure for last year, when the record total of £205,000 worth was imported from this country.

A mobile demonstration unit has been brought into service by the Automatic Coil Winder & Electrical Equipment Co., Ltd., for the display and demonstration of test and measuring equipment. It is now on a **Continental Tour** covering Belgium, Holland, Germany, Denmark and possibly Sweden.



RADAR SCANNERS, d.f. loop and a mast carrying a variety of transmitting and receiving aerials are mounted on the flat roof of the new Marconi House, Melbourne Street, Newcastle-on-Tyne. The depot has a test and repair shop, battery charging room, stores department and offices. In the building are also the Newcastle offices of Marconi Instruments and the English Electric Company.

F

The Ratio Detector

How It Works

By K. R. STURLEY,* Ph.D., B.Sc., M.I.E.E.

THE frequency modulation receiver must perform two functions additional to those required of its amplitude modulation counterpart. These two functions are:

1. The suppression of any amplitude modulation of the f.m. carrier due to noise, interference or variation of response over the receiver passband and

2. The conversion of the frequency deviation of the carrier to an amplitude variation directly proportional to the frequency deviation.

There are many methods of suppressing amplitude modulation: diodes so biased that their loading effect on the circuit varies with the applied signal: a saturated amplifier having an amplification factor inversely proportional to the amplitude of the input signal: waveform slicers that square the waveshape. The most satisfactory type of amplitude limiter is the saturated amplifier, whose output is constant and independent of the input after a certain value of input has been exceeded. Its main disadvantage is that it introduces attenuation because its output is generally less than its input and it adds to the cost of the receiver.

The great value of the ratio detector is that it combines the role of amplitude limiter with that of frequency-to-amplitude converter, and at the same time gives appreciable gain. At its best it is not as good as the saturated amplifier followed by a frequency-to-amplitude converter, but a previous article[1] has given the difference in signal-to-noise ratio as only 2dB. Seeley and Avins, who were the inventors of the ratio detector, describe how it works and indicate the salient design points, but their article[2] is not easy to follow. There have been some attempts since to suggest a simple explanation of its operation but none that the author has seen have been at all convincing and some have left "confusion worse confounded." This article hopes to remedy the position, so let us start with a statement of what the ratio detector is.

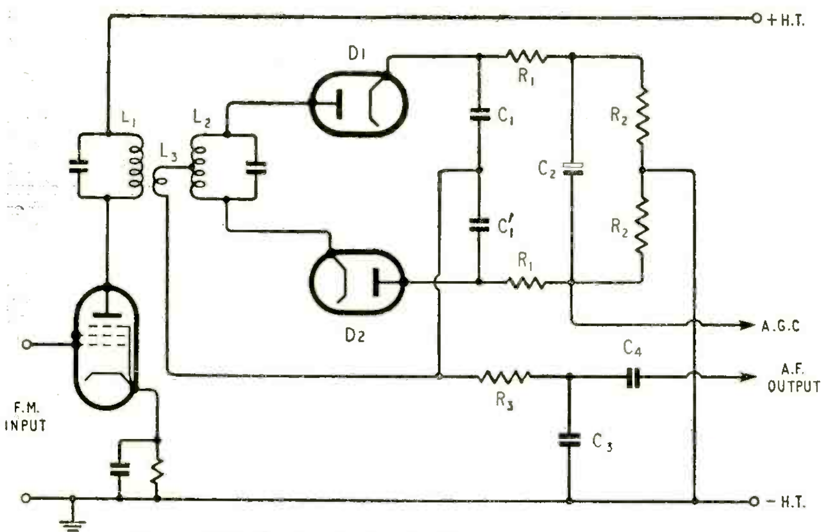
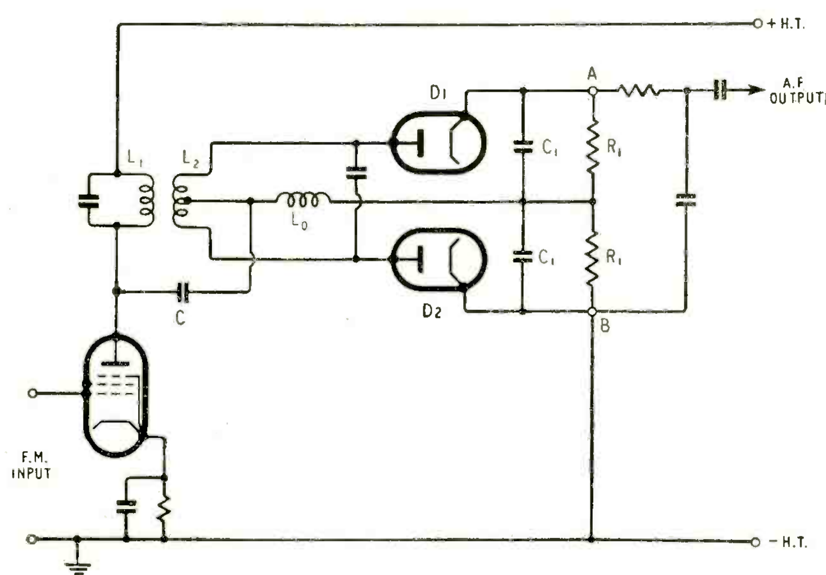


Fig. 1. Typical ratio detector circuit.

Below : Fig. 2. The phase discriminator.



The ratio detector is a modified form of the phase discriminator with the diodes performing the dual role of detection and variable damping. It functions in the same way as the phase discriminator to convert the frequency-modulated input to a combined frequency- and amplitude-modulated signal. Its diodes are so arranged that they provide variable damping to any undesired amplitude modulation already present at the input, reducing overall gain when the signal amplitude tends to increase and increasing it when signal amplitude falls.

There are many possible variants of the ratio detector, but a common form is shown in Fig. 1. As with the phase

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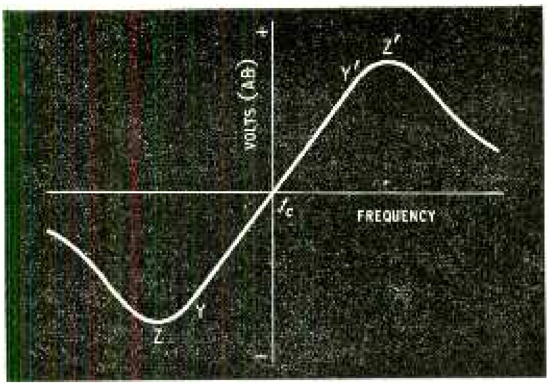


Fig. 3. Output voltage/frequency curve for phase discriminator.

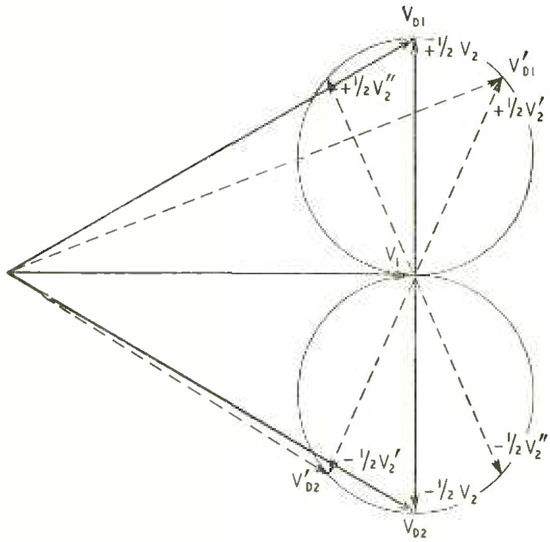


Fig. 4. Vector diagram of phase discriminator.

discriminator each diode obtains its driving voltage from the primary (common to both diodes) and from a half secondary. In this case the primary voltage is derived via a tightly coupled tertiary winding L_3 giving a voltage step-down of about 0.6. The reason for this is that otherwise diode damping is too great on the primary. The diodes are not connected back-to-back as in the phase discriminator but are in series, with the cathode of one joined through a resistance-capacitance load to the anode of the other.

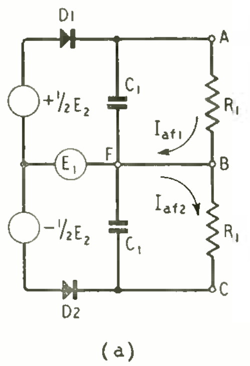
First let us discuss the action of the diodes in detecting the amplitude change of the f.m. signal. We can best approach an explanation via the normal phase discriminator shown in Fig. 2. The secondary of the coupled circuits is centre-tapped, and half its voltage in series with the primary is applied to a diode D1 and the other half also in series with the primary is applied to a second diode D2. The primary voltage is developed via capacitor C across the r.f. choke L_0 between the centre tap of the secondary and the centre point of the diode load resistors. The outputs of the two diodes are connected in phase opposition, and an overall output voltage/frequency curve similar to that of Fig. 3, is obtained when the primary and secondary are tuned to the carrier unmodulated frequency. By correct choice of coupling and damping of the circuits, a linear conversion from frequency to amplitude change is obtained between the two limits YY'. The reason for the S shaped curve of Fig. 3 is best explained by reference to the vector diagram of Fig. 4. The primary voltage vector is V_1 and the two half-secondary voltage vectors $\pm\frac{1}{2}V_2$ are shown in phase opposition because of the centre tap. At resonance the primary and secondary vectors are at right angles, but for other frequencies greater or less than resonance the two secondary vectors are tilted to positions such as, for example, $\pm\frac{1}{2}V_2'$ and $\pm\frac{1}{2}V_2''$ respectively. The amplitudes of the secondary vectors decrease as the off-tune frequency increases, and their loci are the circles shown. The primary voltage vector does not appreciably change its length until the off-tune frequency is large. Assuming V_1 remains constant, we see that the voltage V_{D_1} and V_{D_2} applied to the diodes have maximum values when the secondary vectors are at approximately 45°. This explains the turn-over points Z and Z'.

Let us now take the simplified phase discriminator circuit of Fig. 5(a), and see what happens to the detected voltages across the diode load resistors R_1. When the carrier frequency is unmodulated and the phase discriminator is correctly aligned, the magnitude of the r.f. voltage applied to D1 is the same as that applied to D2, so that the d.c. voltage across AB is equal and opposite to that across BC, giving zero voltage across AC. For example, V_{AB} might be + 3 volts and V_{BC} −3 volts. If the carrier frequency is increased to $(f_c + f_d)$, V_{AB} might rise to +4 volts and V_{BC} fall to −2 volts, giving a total change of 2 volts across AC. A sinusoidally frequency deviated carrier would produce the waveforms shown in Fig. 5(b). Though the d.c. voltages across AB and BC are of opposite polarity, the audio-frequency changes across these points are of the same sign and add to each other to give

$\Delta V_{AB} = \Delta V_{BC}$

and $\Delta V_{AC} = \Delta V_{AB} + \Delta V_{BC} = 2\Delta V_{AB}$

The audio-frequency voltages across AB and BC will cause a.f. currents I_{af1} and I_{af2} to circulate in ABF and CBF as shown in Fig. 5(a). These two currents are equal and opposite in the centre limb and cancel each other. As far as the audio frequencies are concerned there is no voltage across FB and we could remove the link FB were it not that it provides the



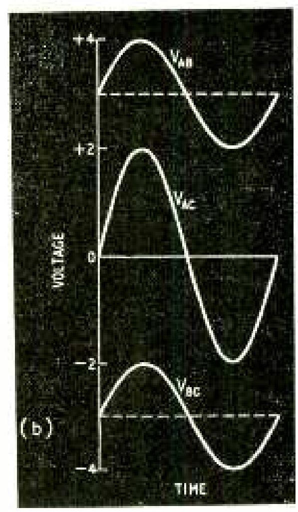


Fig. 5. (a) Simplified phase discriminator circuit. (b) Voltages in different parts of the circuit.

d.c. return path for each diode through the primary generator E_1. The d.c. current from D1 cannot pass through D2 because D2 cannot conduct in the opposite direction. A point worth noting is that when the carrier is at f_c, and the phase discriminator is correctly aligned, there is no output if the carrier is amplitude modulated. We can easily see that this must be so because increase of V_{AB} to +4 and V_{BC} to −4 still gives $V_{AB} = 0$. If the carrier is not at f_c or the phase discriminator is not correctly aligned to f_c, amplitude modulation is not suppressed. Thus if the carrier is at $(f_c + f_d)$, $V_{AB} = +4$ and $V_{BC} = -2$ giving $V_{AC} = 2$: amplitude modulation increasing the carrier amplitude by 50% takes V_{AB} to +6 and V_{BC} to −3 giving $V_{AC} = 3$. That is why we find that when an f.m. receiver is tuned in, background noise, which is mainly amplitude modulation, is a minimum when the receiver is correctly tuned to the incoming carrier. It is one way in which one can ensure that tuning of an f.m. receiver is correct.

Let us now turn, to the ratio detector, whose simplified circuit is as shown in Fig. 6(a). Diode D2 has been reversed and the link FB removed. Removal of this link does not open-circuit the d.c. return path because D2 can now take the current from D1. Reversal of D2 has had another effect, for the d.c. voltage across AB must have the same polarity as that across BC, so that if $R_1 = R'_1$ and the r.f. voltages applied to the diodes are the same as for the phase discriminator.

$V_{AB} = V_{BC} = 3$ volts.

and $V_{AC} = V_{AB} + V_{BC} = 2V_{AB} = 6$ volts

Since the two capacitances C_1 and C'_1 are equal they will also be charged to 3 volts each, and the voltage across FB will be zero.

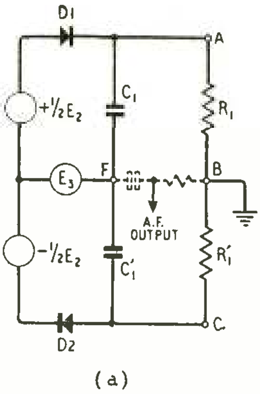
Let us imagine that the carrier frequency increases to $(f_c + f_d)$. The r.f. voltage applied to C_1 increases to produce a d.c. voltage after detection of 4 volts whilst that across C'_1 decreases to 2 volts. The total voltage across A and C is unchanged at 6 volts, i.e., no a.f. voltage is developed across AC when the carrier is frequency-modulated. It is this fact which makes possible the use of the diodes for variable damping as well as detection. We could connect a large capacitor across the points AC without disturbing the detection of f.m. waves though we will appreciably affect the detection of amplitude modulation initially present on the f.m. wave. We shall see later that this is just what is required to give variable damping.

Since the voltage across AC remains at +6 volts, it follows that the voltage across BC is also constant at +3 volts. Now the voltage across FB is

$V_{FB} = V_{FC} - V_{BC} = 2 - 3 = -1$ volt.

Conversely when the carrier frequency falls to $(f_c - f_d)$ the voltage of F rises to +1 volt above B. Thus when f_d is varying sinusoidally we have an a.f. voltage across FB and if we earth B we can take off an a.f. voltage from F through a suitable CR network to the a.f. amplifier valve. The a.f. coupling capacitance is necessary, for we must not disrupt the d.c. path by offering an alternative through E_3.

Provided the ratio detector is correctly aligned and balanced about B we find that like the phase discriminator it suppresses all ampli ude modulation when the carrier is at f_c. For example increase of carrier amplitude merely increases the voltages FC and BC together and their sum is always zero: the $C_1R_1C'_1R'_1$ is a balanced bridge circuit at f_c. At any other frequency the amplitude modulation is not suppressed. Failure to suppress amplitude modulation at f_c



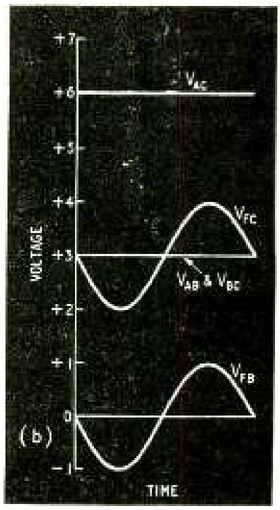


Fig. 6. (a) Simplified circuit of the ratio detector. (b) Voltages across different parts of the circuit.

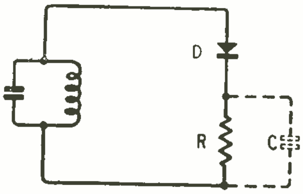


Fig. 7. Tuned circuit shunted by a resistance load.

can occur due to out-of-balance. Thus if $R'_1 = 0.9R_1$ amplitude modulation suppression occurs at some carrier frequency $f_c + \Delta f$ giving a division of voltage across C_1 and C'_1 of 1 to 0.9.

The waveforms of the various voltages in the circuit when the carrier is frequency-modulated are shown in Fig. 6(b). A significant difference between the ratio detector and phase discriminator is that the a.f. output voltage, V_{FB}, is only half that, V_{AC}, available from the phase discriminator, i.e., there is a 6dB loss from the ratio detector connection. If this were all that resulted, the ratio detector would certainly not be popular. This disadvantage can, however, be offset because the series connection of the diodes and the fact that there is no a.c. voltage across the points AC allow the diodes to be used as a variable damping resistance without impairing their detection characteristics.

Before dealing with the changes necessary to allow the diodes to function in this manner, let us see what happens when a diode is shunted across an r.f. tuned circuit. In Fig. 7 a diode is shown in series with a resistance R across a tuned circuit. If the diode is a perfect unidirectional device of resistance R_d and there is no capacitance across R, not even strays, the diode conducts on each positive half wave and during this time reflects a resistance $R_d + R$ across the tuned circuit. Since this operates half the time it will be equivalent to $2(R_d + R)$ for the whole cycle. When R is shunted by a capacitance C and the time constant CR is much greater than $1/f_c$ but much less than $1/f_a$(max), where f_a(max) is the maximum audio frequency, two things happen to the r.f. current taken by the diode:—

(1) it will increase many times in value, and

(2) the time during which it lasts will be appreciably reduced.

The r.f. current increases because the capacitance short-circuits R and its value is only limited by the voltage applied, the diode resistance R_d and the internal resistance of the r.f. voltage source. The time during which current occurs is reduced because the CR combination acts as a self-bias circuit preventing diode conduction until this self-bias voltage is exceeded. Current amplitude is increased to a greater extent than duration is shortened, so that the energy taken from the tuned circuit is greater. The result is that the diode presents a resistance R_E of about ½R to the tuned circuit.

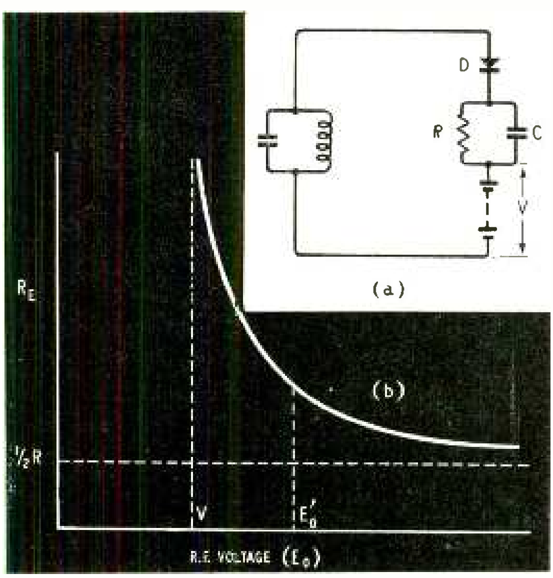
With both types of circuit there is practically no change of resistance reflected from the diode with change of r.f. voltage amplitude, and this method of damping is of no use to us. Let us now take a diode with a CR circuit and apply a fixed bias voltage V of polarity to stop conduction (Fig. 8(a)). Until the r.f. voltage initially exceeds V no current flows and there is no resistance across the tuned circuit from the diode. When the r.f. voltage greatly exceeds V the action of the diode is almost independent of V and determined only by its CR circuit: it then reflects a resistance of ½R across the tuned circuit. At intermediate voltages the resistance is greater, so that if we plot a curve of equivalent resistance R_E from the diode against r.f. voltage we should get a relationship like that of Fig. 8(b). This does show the kind of variable damping characteristic we require, for resistance decreases as amplitude increases. If we operate with the tuned circuit in the anode of a pentode at an r.f. voltage of E_0' (Fig. 8(b)), any change of E_0 would produce a change of R_E and vary the gain of the pentode in a direction opposite to the input amplitude change causing it. As an example let us assume the following conditions

Tuned circuit dynamic impedance, $\frac{L}{CR} = 0.5M\Omega$

g_m of valve = 5mA/V

Equivalent resistance of diode at $E_0 = 9.8V$, $R_E = 40{,}000\Omega$; $E_0 = 10V$, $R_E = 20{,}000\Omega$; $E_0 = 10.2V$, $R_E = 13{,}000\Omega$.

Fig. 8. (a) Tuned circuit shunted by a biased diode with RC load. (b) Resistance (R_E) reflected from diode, plotted against r.f. voltage.



The anode load of the pentode consists of R_E in parallel with 0.5MΩ, and the latter is large enough to be neglected. The gain of the valve at the different values of E_0 will be $g_m R_E$, viz.,

E_0	*Gain*	*Input Voltage*
9.8	200	0.046
10.0	100	0.1
10.2	65	0.154

We see that, with the value we have chosen, an input voltage change equivalent to 50% amplitude modulation has been reduced to a 2% amplitude modulation of the output voltage. A still greater reduction of amplitude modulation could be obtained by a greater change of R_E.

If a diode is to be used in a receiver as variable damping the fixed bias voltage can easily be obtained from the h.t. supply, but the effectiveness of the damping will be confined to a comparatively small range of output voltages about E_0'. Such a scheme would not be satisfactory in a receiver which was designed to accept either weak or strong signals and which had no additional limiting action before the diode damper. The ideal arrangement would be to have the bias voltage variable to suit the output voltage, decreasing bias when the output voltage is less than E_0' (Fig. 8(b)) and increasing bias when the output voltage is greater. This would allow us always to operate on the part of the $R_E - E_0$ curve giving the best amplitude suppression. This can be achieved by letting the diode provide its own self-bias, using an RC combination whose time constant is much longer than the reciprocal of the lowest amplitude modulation frequency likely to be encountered, i.e., about 0.1 sec corresponding to a frequency of 10 c/s. The circuit would be as shown in Fig. 9. C_1 and R_1 would be

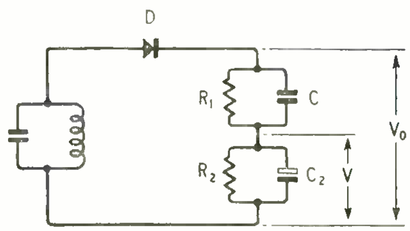


Fig. 9. Variable damping diode.

about 300pF and 1000Ω and C_2 and R_2 25μF (electrolytic) and 10,000Ω. Minimum damping resistance would be $\frac{1}{2}R_1$ to any amplitude modulation change and we should have variable damping similar to that shown by the curve in Fig. 8(b). The operating output voltage E_0' will have a definite relationship to the bias voltage V and will be approximately $\frac{V_0}{0.9} = \frac{R_1 + R_2}{0.9R_2}V$; the 0.9 is included to allow for a diode detection efficiency (ratio of d.c. voltage to peak applied voltage) of 90%. If R_1 is made zero the output voltage operating point is almost coincident with V, the $R_E - E_0$ curve is very steep falling to almost zero damping resistance, and the diode suppresses (or considerably reduces) any positive amplitude change. For any negative amplitude change there is no damping from the diode because the bias V holds it non-conducting. Seeley and Avins refer to this condition as fully stabilized because all the detected d.c. voltage is used as the bias voltage V. It is obviously an undesirable condition in which to work and the more normal method is to operate with about 80% of the detected d.c. voltage stabilized, i.e., used as the bias. With this degree of stabilisation, the variable damping detector should appreciably reduce input voltage amplitude modulation of as much as 90% in either positive or negative direction. Naturally the amount of suppression in the negative direction will be determined by the undamped Q of the secondary and also the primary coil, since maximum gain cannot exceed the undamped gain. Q_2 and Q_1 should therefore be as high as possible.

So far we have discussed the effect of diode damping to any change of carrier amplitude, but it is also essential to know what the damping will be to a constant carrier amplitude because this will determine the gain of the stage to a frequency-modulated signal. The equivalent resistance reflected into the tuned circuit from the diode in Fig. 9 at a constant carrier amplitude is determined not by R_1 alone but by the sum of $R_1 + R_2$, and it will in fact be nearly $\frac{1}{2}(R_1 + R_2)$. This is very important because it means that the gain of the stage to a frequency-modulated constant-amplitude signal can be reasonably large and the heavy damping is only effective on carrier amplitude changes. We are in fact making use of a low ratio of a.c./d.c. load in the diode circuit: only the d.c. load affects the carrier amplification whereas the a.c. load damps any changes in carrier amplitude.

Having explained the principle of variable damping by diodes let us now see how it is applied in the ratio detector to provide amplitude limiting. Let us imagine that we have a centre-tapped tuned circuit across which we wish to have variable damping. Clearly

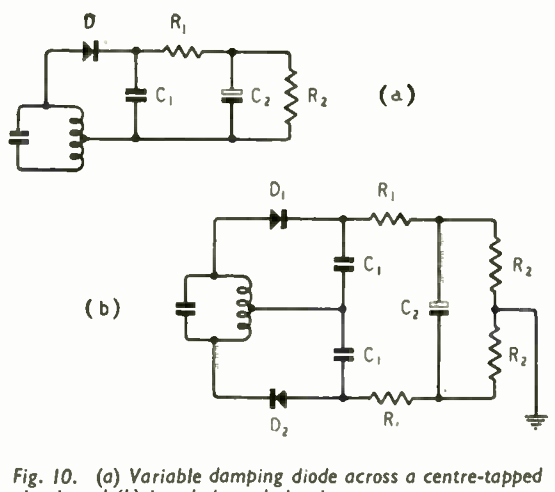


Fig. 10. (a) Variable damping diode across a centre-tapped circuit and (b) in a balanced circuit.

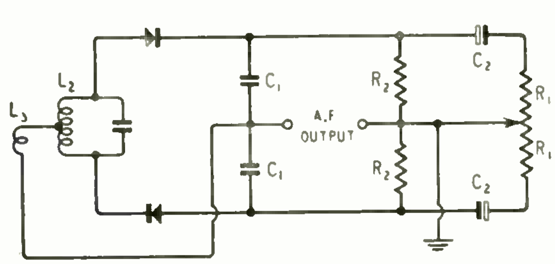


Fig. 11. Alternative ratio detector connection.

we could place across one half of the circuit the variable biased diode as shown in Fig. 10(a). The r.f. bypass capacitance C_1 is shown connected direct to earth instead of to the junction of R_1 and R_2 as in Fig. 9. This has no effect on the operation of the circuit, but it does ensure that the r.f. performance is not influenced by possible inductance in the C_2 leads. Since the centre-tapped circuit is balanced it is preferable to have a balanced damping circuit and this can be realized by using two diodes connected in series across the whole tuned circuit with their common load resistance centre-tapped to earth, as in Fig. 10(b). It is only one step from Fig. 10(b) to the ratio detector of Fig. 1. The link from the centre of the coil to the junction of capacitors C_1 is replaced by the tertiary coil. We have already shown that frequency modulation of the carrier produces an a.f. signal across the two capacitances C_1 in Fig. 10(b) and that the resistance arm $(2(R_1 + R_2)$ carries only a d.c. current and no audio frequency. It is therefore possible to connect a large capacitor across a whole or part of the resistance without affecting the performance of the circuit as a detector of frequency modulation.

We have seen above that the large capacitance must not be used across the whole of the resistance load, otherwise no suppression of negative amplitude modulation occurs. Even if the negative modulation problem did not exist we could not use a large capacitance across all the resistance because if there were a quick reduction in amplitude of the f.m. carrier the bias could not fall fast enough and the diodes would be cut off. We should then have either no audio-frequency output from the f.m. carrier or else a very distorted output.

Suitable values for the components in Fig. 1 are $C_1 = 330$pF: $C_2 = 16$ to 25μF (electrolytic), $R_1 = 1000\,\Omega$, $R_2 = 6800\,\Omega$. R_3 and C_3 are selected to give the required de-emphasis of the audio frequencies, possible values are $50{,}000\,\Omega$ and 1000pF and C_4 (0.01μF) is the audio-frequency coupling capacitance. With the component values quoted above the damping resistance effective at constant carrier amplitude will be approximately $(R_1 + R_2) = 7800\,\Omega$ across the complete secondary and $\frac{1}{4}(R_1 + R_2) = 1950\,\Omega$ across the tertiary winding. The reason for the lower damping resistance across the tertiary is that the r.f. currents from each diode traverse the tertiary coil. Since the tertiary winding has a step-down of about 0.6, the resistance reflected across the primary will be $1/(0.6)^2$ of that across the tertiary, i.e., it will be about the same as that across the secondary. This explains why a tertiary is essential in order to reduce the damping on the primary and so increase overall gain to the f.m. signal. Any amplitude modulation of the f.m. carrier will see an effective variable resistance whose minimum value is $R_1 = 1000\,\Omega$ across the secondary and $250\,\Omega$ across the tertiary.

Many factors contribute to optimum amplitude limiting and not least the design of the coupled circuits, the undamped Q of which (particularly the secondary) should be as high as possible if effective suppression of negative amplitude modulation is to be achieved. A suitable design has already been given in this journal[3]. It is important, too, to operate the circuit in the balanced condition at the unmodulated carrier frequency, f_c. This is achieved by adjustment of one of the R_1 resistances until a.f. output is a minimum when an amplitude-modulated input carrier of frequency f_c is applied. The resistances R_2 should have tolerances of $\pm 1\%$. Amplitude suppression is, of course, obtained from diode damping when the circuit is not balanced, but the suppression will be less effective when the carrier deviation, f_d, is positive than when it is negative, or *vice versa*.

Since the ratio detector offers a fixed damping resistance to any steady value of carrier amplitude it will be clear that a "semi-permanent" change in carrier amplitude must produce a corresponding change of audio-frequency output from the frequency-modulated carrier. Hence tuning from a strong to a weak incoming signal will cause the a.f. output to fall. With the saturated amplifier limiter there is no change in a.f. volume and we have perfect automatic gain control (a.g.c.) characteristics.

This disadvantage of the ratio detector can be partially overcome by using the d.c. voltage developed by the ratio detector diodes to provide an a.g.c. voltage to bias preceding i.f. amplifier stages. The point from which a.g.c. could be obtained is indicated in Fig. 1. An alternative ratio detector circuit is shown in Fig. 11: the main difference between it and Fig. 1 is that the resistances R_1 are placed in series with C_2 which is split into two capacitors to maintain circuit balance. Adjustment of the earth tapping point on R_1 gives fine control of balance.

To sum up, we see that the success of the ratio detector is due to the fact that the resistance load of the diodes carries no audio frequency when the carrier is frequency-modulated. This allows us to use a low ratio of a.c. to d.c. load and by this means suppress amplitude change on the carrier.

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[2] Seeley, S. W. and Avins, J. "The Ratio Detector," *R.C.A. Review*, Vol. 8, June, 1947, p. 201.

[3] Amos, S. W. and Johnstone, G. G. "Design for an F.M. Tuner." *Wireless World*, May, 1955, p. 216.

LETTERS TO THE EDITOR

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

Fourier—Fact or Fiction?

IN his article on Fourier analysis in the September *Wireless World*, "Cathode Ray" becomes confused because of careless use of the term "frequency."

He gives a simple and valid definition of frequency; viz., the rate at which identical events occur. It follows that any waveform can have one and only one frequency and it is meaningless to ask whether a waveform having only one frequency is necessarily sine. It is not necessarily anything.

Fourier's theorem states that any periodic function can be made up from a number of sine functions of different frequencies. It is common usage to say that a waveform contains frequencies other than its own, when what is meant is that the waveform can be made up from sine waves of these other frequencies, together with a sine wave of the fundamental frequency. The difficulty arises when "Cathode Ray" uses the word frequency without referring it to any particular waveform.

For instance, in asking what frequencies a sine waveform may contain, we are really asking what sine waves, with their harmonics, are needed to make it up. The answer is obviously the pure fundamental, which is where we came in.

Southampton. G. F. FOOKS.

"CATHODE RAY" wishes, on p. 456 of the September issue, that some mathematician would chip in with a neat proof to support his arguments; but unfortunately the theorem he was hoping for is false. I have sent for his criticism what I think is a fairly neat proof that any waveform (within reason) together with the same one moved $\frac{1}{4}$ the way along the wavelength (the same relationship as the sine to the cosine) can be used at frequencies 1, 2, 3 . . . . times that of another given wave function, to analyse the latter in "components" of the former.

So "Cathode Ray" is right to proceed to look for other features of the sine in order to justify its preference, and I admire the reasons he gives. But he overlooks one important one; namely, that with sines and cosines, the coefficients in the Fourier series (i.e., the amplitudes of the harmonics) are relatively easy to compute; if we had used any other basic waveform they would have been very much more difficult.

Braunstone, Leicester. J. P. DOUGHERTY.

"Cathode Ray" replies:—

It is hardly surprising that my metaphysical musings on Fourier in the September issue aroused some comment, not to say protests.

Some correspondents have shown themselves still unable to look at the sine waveform with an open mind. G. F. Fooks scores a definite point, I think, in his criticisms. But even he lapses into sine worship in his last paragraph. My whole point was that, however advantageous it is in practice to regard sine waves as basic, in principle one could choose otherwise.

J. P. Dougherty has supported me in this with a mathematical proof, which looks all right, though I am not mathematician enough to pronounce with authority on its validity. Incidentally, what he seems to have taken for an appeal to establish the sine wave as the only possible basis of a "Fourier" series was intended to be a challenge. His proof that other waveforms could be used relieves me of the fear that someone would successfully accept the challenge, and I am much obliged to him for his mathematical blessing on what might seem my rather presumptuous questioning of the divine right of sines.

With regard to his second point, I thought I had at least implied it in the words (p. 457) "So if electrical engineering (for example) were based on any other waveform, the whole thing would be unbearably complicated and difficult." But it is just as well to have it stated plainly.

I am indebted to J. F. Stray for referring me to Eddington's "Philosophy of Physical Science," Chap. VII, in which Sir Arthur contends that some so-called laws of nature are in fact man-made. He likens these to a "law" a sculptor might propound—that shapeless blocks of marble naturally contain the form of a human head, his evidence being that such a form can be isolated by means of an experimental analysis using a hammer and chisel. What I would like to ask the distinguished author is what view he would take of the matter if the chips were all found to be of identically the same human form, and of sizes that were exact integral sub-multiples of the main head. "CATHODE RAY."

Neon Tuning Indicator

IN the article by John D. Collinson on page 429 of the September issue it is stated that "With finite values of μ and R_k the anode current changes will not be equal and opposite, but unbalance is immaterial as it reduces to zero at the working point." The second part of the statement is surely incorrect.

The changes in anode current do not matter provided the anode currents passed by each half of the valve at the working points are equal and that the mean characteristics are equal. In short, the two halves of the circuit must be balanced statically at the working point.

In practice this seems very unlikely, especially as no selection between valves is possible since these will usually be in the same envelope. This is easily confirmed by shorting the input to the indicator and it will be seen that the neons do not glow equally except in exceptional choice of components. This means that the indicator will not indicate zero voltage for equal neon brightness but will indicate a constant error voltage, the error depending on the static unbalance of the circuit.

This difficulty may, of course, be overcome by inserting a small resistance in the cathode lead of one-half of the valve, thus altering the standing current balance and making the neons glow equally for zero input voltage.

The statement that the indicator indicates balance to within ± 3 kc/s thus seems unjustified.

I should add that I am using the modified form of this indicator with a ratio detector and find it gives excellent results,

North Harrow, Middx. A. LIONEL WILLIAMS.

The author of the article writes: I agree that the unbalance only reduces to zero at the working point with perfectly balanced valves. The suggested modification is therefore valuable if it is thought that errors due to normal valve unbalance are serious.

In practice, however, it seems that commercial double triodes balance rather better than Mr. Williams implies. In the circuit given, a 20 per cent unbalance between anode currents requires 75 mV to bring them into balance. With a discriminator output of 100 mV per kc/s deviation this corresponds to a tuning error of ±750 c/s.

The figure of ±3 kc/s quoted actually includes the expected valve error together with the human error in estimating the relative brilliance of the neons, the latter error being the greater. JOHN D. COLLINSON.

"Etched Foil Printed Circuits"

H. G. MANFIELD is to be congratulated on the very interesting and informative article in your September issue.

However, neither with nor without the benefit of Crown Copyright does copper liberate hydrogen from nitric acid and it is suggested that the word "gas" be substituted for "hydrogen" in an otherwise outstanding article.

Hornchurch, Essex. L. D. STUART.

Television Aerial Feeders

"DIALLIST'S" comments on balanced *versus* unbalanced television aerial feeder cables in your August issue conflict with my own experience so I cannot let them pass without some comment.

I have conducted reasonably careful tests using coaxial cable and both screened and unscreened twin cable and I concluded that:

(a) Feeder pick-up was only important when the feeder cable was in a strong interference field remote from the aerial (e.g., a long feeder cable in a building running very close to power supply cabling carrying a considerable level of interference signals, the aerial itself being mounted outside and well above the building).

(b) When there was appreciable feeder pick-up, the type of cable was unimportant but the preciseness of the match to the receiver was all important. A twin feeder connected to an unbalanced input was as bad as a coaxial feeder connected to a balanced input.

As "Diallist" will be aware, to achieve a good balanced input to a receiver is not all that easy. Even careful attention to the design of the input circuit and care in positioning components will rarely produce a balance-to-unbalance ratio at v.h.f. much better than 20 dB. Certainly a turn or so of wire over the grid coil of the first stage with both ends brought out to a second- or third-rate socket cannot possibly give a balanced connection.

I have yet to meet a commercial TV set with a balanced input worthy of that description or with a twin aerial feeder socket really suitable for use at v.h.f. and I suspect that the cost of providing a really good balanced input is likely to make the most enthusiastic manufacturer jib. In these circumstances, since we are both agreed that good matching at the receiver input is essential, it would be better to recommend the set maker to stick to his unbalanced input and the set owner to install coaxial feeder cable.

Cheltenham, Glos. T. A. LEWIS.

"Back to Methuselah"

I AM not sure what to make of "Free Grid's" reference to W. T. Cocking and myself as "irregular" contributors, coming as it does from such a source. However that may be, his crediting me with a mere 28 years' irregularity jerked me up out of my bathchair to seize reed pen and papyrus. If "Free Grid" will turn up the issue dated August 15th, 1923 (i.e., over 32 years ago), he will see on page 660 my contribution on a voltage raiser for valve transmitters. (Note particularly, *valve* transmitters.)

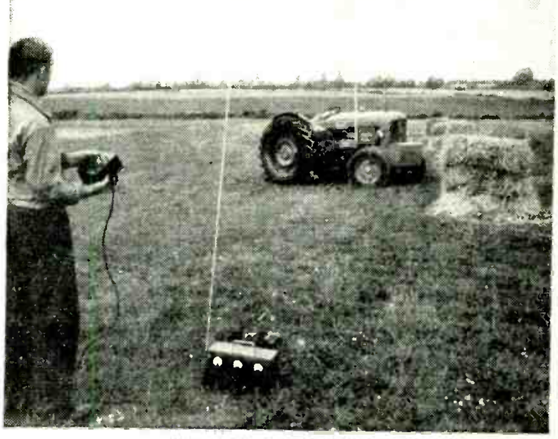
On the other side of the page he may be interested in the photograph of an up-and-coming youngster, called Captain Eckersley, inspecting the new B.B.C. apparatus (installed in the studio!) for relaying the London programme to transmitters in other parts of the country. I am sure "Free Grid" would find the wiring of this equipment a fit subject for one of his entertaining comments.

Bromley, Kent. M. G. SCROGGIE.

Magnetic Tape

ALTHOUGH a number of theoretical claims have been made that tape recordings can be stored for extended periods, it would be interesting to know if any reader has stored a tape for five years and finds that its original quality has deteriorated by "print through" or other causes.

Pinner, Middx. A. H. BEAN.



Driving a diesel farm tractor by radio control is hardly likely to become general practice, but it has been introduced by Ford's as a novel method of demonstrating their Fordson Major. There are six controls covering steering (L & R), clutch, implement lowering and raising, and engine switch. The radio equipment, which was designed by G. Honnest-Redlich, of Radio & Electronic Products, is operated on the tone-modulated carrier system, the carrier being 27.12 Mc/s and the modulating frequencies between 250 and 400 c/s.

Dual-band Television Aerials

1—*Alternative Designs for Combined Band I and Band III Reception*

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

BY now everybody concerned with television understands that Band I is the frequency spectrum embracing the five existing B.B.C. television channels and Band III is the v.h.f. spectrum which will ultimately be devoted, exclusively, to television and will be divided into eight channels. In round figures Band I covers from 41-68 Mc/s and Band III from 175-215 Mc/s. This brings one to the first important point, namely, the frequency ratio of Band III to Band I. The lowest value is about 2.6/1 and the highest is about 5.3/1.

Consider a simple vertical half-wave dipole resonant at 45 Mc/s (Fig. 1). For a vertically polarized wave arriving normal to the axis of the dipole (see the arrow) this aerial will develop an open-circuit e.m.f. across its terminals x, y, given by:

$$e_0 = \frac{E\lambda}{\pi} \qquad \cdots \qquad (1)$$

where E is the incident field strength in volts/metre and λ is the wavelength of the radiation.

Notice that the vertical directional characteristic as given by the dotted line shows a maximum in the direction of arrival normal to the dipole axis.

In these conditions the dipole is equivalent to a generator possessing an internal resistance of approximately 80 ohms and if terminated by an 80-ohm load, conveniently through a transmission line of characteristic impedance $Z_0 = 80$ ohms, the voltage across the load will be given by:

$$e_1 = \frac{E\lambda}{2\pi} \qquad \cdots \qquad (2)$$

assuming that the line losses can be neglected.

This is all well known but has to be reintroduced as the basis for considering what happens when one attempts to use the same aerial at frequencies other than the fundamental resonance, and particularly over the Band III spectrum.

Three effects must be taken into consideration because they all act in a way which reduces the e.m.f. at the terminals x, y, and which can never attain the value at half-wave resonance if loaded with 80 ohms. First, the induced e.m.f. becomes a most complicated function of frequency. Second, the impedance as seen at the terminals varies with frequency. It is high (several hundred ohms) when the frequency ratio is about an even integer and falls to about 80 ohms when the ratio is about an odd integer. Third, the vertical directional characteristics split up into a number of lobes and never show a principal maximum in the direction of arrival normal to the axis of the dipole, which is the direction which is used for all practical purposes. A particularly bad case is when the ratio is 4 to 1 in which case the induced e.m.f. is zero at normal incidence (Fig. 2). This would result in minimum signal reception and maximum interference from aircraft (flutter) and ignition interference.

*Belling and Lee Ltd.

It is beyond the scope of the article to analyse these three effects because it involves laborious mathematics and seems to defy simple explanation. It is one of those problems which is best solved by experiment and measurement. Perhaps one of the reasons why no one has bothered much about it is because it would be bad engineering to attempt to use a resonant dipole at far-removed frequencies, but the television aerial installer should be in a position to know just how Band I aerials behave on Band III, particularly on certain channels. It so happens that the range of Band III/Band I ratios (2.6 to 5.3) provides all the conditions for adverse performance, from gross mismatch to the load impedance, to splitting up of the vertical directional characteristics.

Very careful measurements have been made of the relative gains of Band I aerials over the Band III spectrum and the results are shown in the family of curves of Fig. 3. A resonant dipole on each Band I channel was fed through a balanced 80-ohm transmission line to an 80-ohm load, and thence to an accurately calibrated measuring receiver. Spot measurements were taken at each of the eight channels on Band III, (a) with the Band I aerial under consideration, and (b) with an optimized resonant half-wave dipole on the Band III channel under consideration. The ratio of these two amplitudes expressed in dB

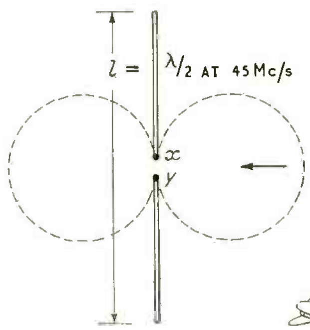


Fig. 1. Simple half-wave dipole showing the vertical directivity at 45 Mc/s.

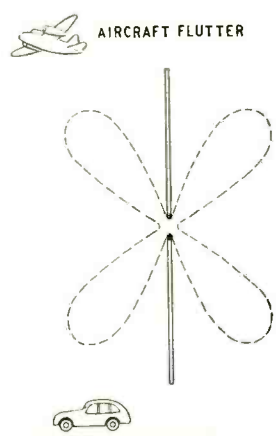


Fig. 2. Vertical directivity of 45-Mc/s dipole at 180 Mc/s.

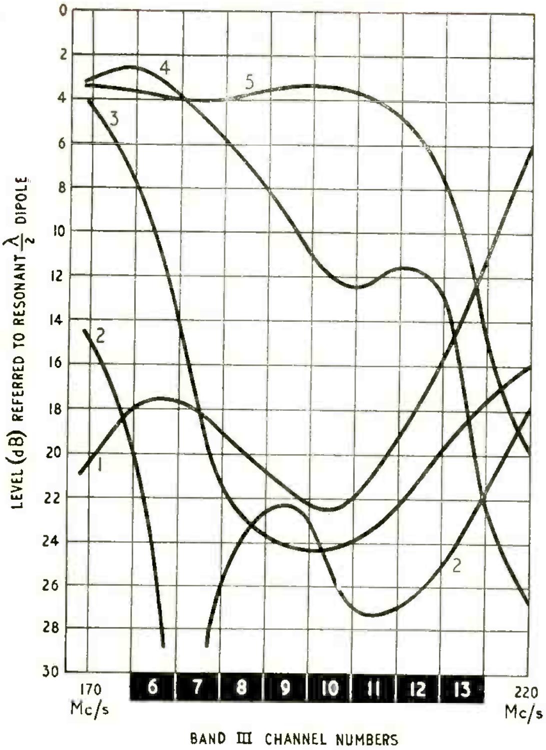


Fig. 3. Response of Band I dipoles (Channels 1-5) over Band III.

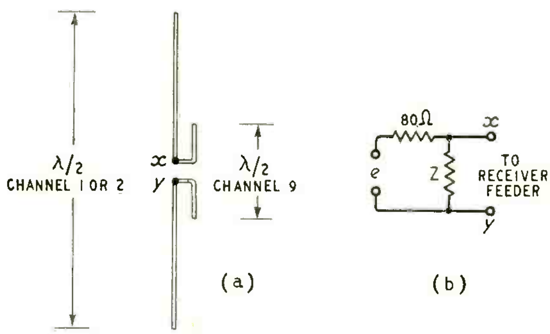


Fig. 4. Channel 1 or 2 dipole adapted to provide Channel 9 reception at moderate efficiency.

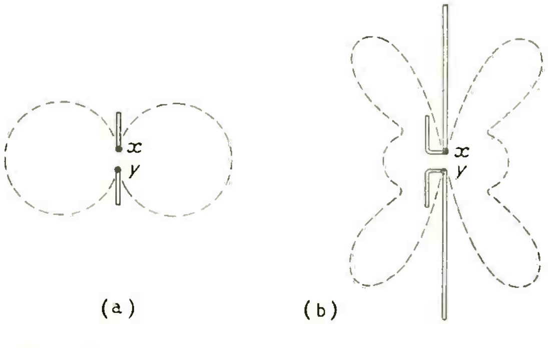


Fig. 5. Showing how the Band III vertical directivity is affected by the Band I elements.

gives the loss one incurs by attempting to use the Band I aerial on Band III.

Apart from this loss, which is particularly high for dipoles designed for Channels 1 and 2, the vertical directional characteristics take the form of lobes directed upwards and downwards thereby increasing the susceptibility of the installation to aircraft flutter in respect of the upward lobes, and ignition interference for the downward lobes (Fig. 2).

The performance of Band I multi-element aerials follows the same pattern over Band III as the simple dipole, because the various parasitic elements are so hopelessly out of resonance that their contributions can be ignored. It would take a great deal of work to check all the possible arrangements, but a few odd measurements support this view.

At the present time we are concerned with the dual reception of Channels 1 and 9 in London, 2 and 9 in Lancashire and 4 and 8 in the Midlands.

It will be seen from Fig. 3 that dipoles for Channels 1, 2 and 3 are extremely inefficient in the middle of Band III where the only television allocations to date exist. Not one of the five dipoles can be said to be moderately efficient over the whole of Band III, but a Channel 4 dipole is reasonably responsive on Channel 8. This observation will be dealt with later.

Notwithstanding the poor performance of Band I aerials on Band III, particularly Channels 1 and 2, there are so many of them that serious consideration has to be given to ways of improving their performance on Band III without introducing any serious loss on Band 1. The attachment of additional elements of appropriate dimensions can effect considerable improvement, but, according to the author's tests, cannot bring the aerial up to the performance of a simple half-wave dipole designed for the particular Band III channel which it is desired to receive. At best the Band III performance is about 3 dB below that of an optimized dipole, that is, with the longer elements wholly removed (Fig. 4(a)).

This method of adaptation is thus quite useful in areas of high Band-III field strengths, but is only usefully confined to Channel 1 (London) and Channel 2 (Holme Moss) dipoles. Both of these exhibit a high impedance at the terminals x, y, on the I.T.A. Channel 9, since the frequency ratio is about an even integer (4/1). Thus we may consider the equivalent circuit on Band III to be a generator with an internal resistance of 80 ohms whose output terminals x, y, (Fig. 4(b)) are shunted by an impedance (Z) of several hundred ohms. In view of the high shunt value of Z why should the performance be measurably inferior to a simple Band III dipole? The answer is, simply, that the vertical directional characteristics are modified because the Band I elements are contributing adversely with their upward and downward lobes. This is best seen by using the dipole as a radiator and transmitting energy from it. For a given energy applied to the terminals x, y, most of it is radiated in all directions at right angles to the axis of the dipole on Band III *if the Band I elements are removed.* On replacing these elements some of this energy is used for radiating upward and downward lobes which serve no useful purpose and must reduce the energy radiated in the desired direction. By the principles of reciprocity the directional characteristics of a given aerial are identical for transmission or reception which proves the point. Fig. 5 may assist the reader in following this explanation.

A better method of converting Channel 1 and 2

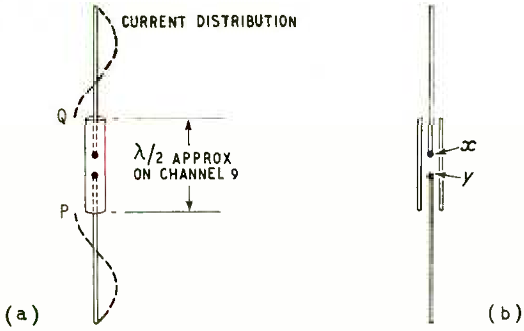


Fig. 6. Co-phased Channel 1-2, 9 conversion.

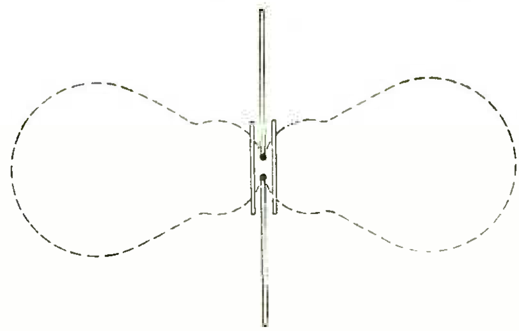


Fig. 7. Vertical directivity of co-phased conversion.

aerials to Channel 9 will now be described.† The Band I dipole is surrounded by a metal sleeve of approximately two inches diameter, symmetrically disposed about the junction (Fig. 6(a)) and is approximately half a wavelength from tip to tip on Channel 9. In practice the cylinder may be dispensed with and replaced by at least two metal rods suitably spaced off with insulators, although one rod does work fairly well. In this arrangement the sleeve (or rods) act as a continuation of the low-impedance coaxial transmission line normally connected to x, y so that at points Q and P, where the current is maximum and the impedance therefore low, there is a reasonably good impedance match. Of course, the current is maximum at Q and P because they are approximately $\frac{3\lambda}{4}$ from the outermost tips on Channel 9, always remembering that we are discussing Channels 1 and 2 dipoles, where the frequency ratio is of the order of four to one. Moreover, the upper and lower elements are fed in phase so that this co-phased conversion should be almost as efficient as *two* resonant Channel 9 dipoles placed one above the other and co-phased. Then the increased gain would be 3 dB. The measured gain of this co-phased conversion is about 2 dB above a simple resonant dipole. A further very good property is seen in Fig. 7 which shows that the vertical directivity is concentrated along the normal direction of arrival of the signal, thereby reducing aircraft flutter and ignition interference to a greater degree than that possible by the former adaptation of Fig. 5.

So far the adaptations described do not confer any horizontal directivity on either aerial. Of course, the Band I aerial can have its usual parasitic reflector and/or directors added to give it horizontal directivity but the Band III performance will still be that of an omni-directional dipole.

Observations on the transmission of the experimental station G9AED (Channel 9) were conducted in a mobile research unit in which the vision signal (test card) could be compared on (a) a simple omni-directional dipole and (b) a three-element directional array. In many instances serious "ghosts," due to delayed reflections, were noticeable when the dipole was in use, but in most cases they were eliminated by changing over to the three-element array. "Ghosts" were certainly far more prevalent on Band III than on Band I as was predicted in an earlier article by the author[1]. Objects such as churches, large blocks of flats, and electricity cable pylons were often responsible, while cooling towers and gasholders were outstandingly bad, and so were sharply rising hills, if they were sited behind the receiving installation. Thus while an adapted Band I dipole may not give rise to "ghosts" on that band there may be serious "ghosts" on Band III.

†Patents pending.
[1] F. R. W. Strafford, "Band III Television Aerials." *Wireless World*, April 1954.

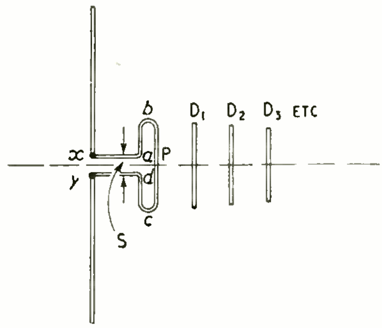


Fig. 8. An adapted Channel 1-2, 9 aerial providing gain and horizontal directivity on Channel 9.

The next step is to design an adaptor which can provide horizontal directivity on Band III, and a neat way of achieving this for Channel 1 and 2 adaptations will now be described with reference to Fig. 8†.

As usual the feeder to the receiver is connected to the Band I dipole terminals x, y, and the folded dipole is correctly dimensional for the Band III channel required, i.e. the distance bc approximates to one half wavelength. Consider the conducting loop $x\ a\ b\ c\ d\ y$; this may be regarded as a section of transmission line short-circuited at the point P. From normal transmission line theory a short-circuited line of length $\frac{n\lambda}{4}$ where n is odd, behaves as a high impedance at its input terminals (in this case x, y). Therefore, by making the length $x\ a\ b\ P$ such that this condition obtains *on Band I* a high impedance is shunted across x, y which will absorb negligible energy, since it is in parallel with about 80 ohms, i.e. the radiation resistance of the Band I dipole, and will therefore not adversely affect its performance.

On Band III the Band I element presents a high impedance at the terminals x, y but the folded dipole which has a terminal impedance at a, d of about 300 ohms on Band III, is transformed down to 80 ohms at the junction x, y by the parallel conductors x, a and y, d by the familiar stub technique. The spacing, S, is chosen to satisfy the characteristic impedance required for the parallel section to achieve the desired transformation from 300 to 80 ohms.

This system may now be made directional by the addition of one or more directors D_1, D_2, etc. The same result could be achieved by connecting the folded dipole terminals *a*, *d* to the plain dipole terminals *x*, *y* by means of a diplexer, which is a combined high-pass low-pass filter with inter-band cut-off frequencies, but the use of a diplexer is confined mainly to other aspects of installations and will be discussed later. In this particular application, however, it is a more expensive way of achieving the same result.

As in the case of the simple adaptations of Figs. 5 and 6 the method can be extended to Band I dipoles possessing a reflector and/or directors.

(*To be concluded*)

New Vision A.G.C. System

Advantages Obtained from an Improved Method of Gating

By S. E. GENT,* B.Sc. (Eng.), Grad.I.E.E., and D. J. S. WESTWOOD,* B.Sc. (Eng.)

WHATEVER the argument for using vision a.g.c. in the past, there is little doubt that, with the advent of Band-III television and the introduction of more than one programme, an efficient system of this kind is now a highly desirable, if not essential, part of all except the very cheapest of receivers.

The main reason for this requirement is the certainty that in most districts the Band-I and Band-III signals supplied to the receiver will be of different strengths, and it will not be desirable for the viewer to have to readjust the gain control of the receiver when switching from one programme to the other. One might argue that this could be overcome by pre-set gain controls in the receiver, one for each channel, which could be adjusted by the service technician and then left. But even if this is accepted for two or even three channels it must be remembered that there will one day be more channels in use, and the prospect of thirteen pre-set gain controls is a little staggering, to say the least! It is to be expected that variations in signal strength on Band III may be more serious than on Band I, and this may be used as a further argument in favour of a.g.c.

The majority of current a.g.c. systems will not deal efficiently with aircraft flutter unless the flutter frequency is very low, but it is claimed that the new system described in this article can be better in this respect than previous systems.

Obviously, in order to deal adequately with comparatively fast changes of signal strength, such as are caused by aircraft flutter, the time constant in the a.g.c. smoothing circuit must be short, and the a.g.c. voltage must be derived entirely from the vision signal and must be independent of the picture information and the sound signal.

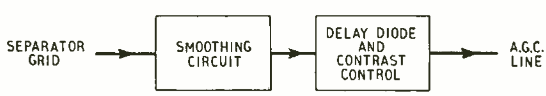


Fig. 1. Simple a.g.c. system using mean d.c. voltage at sync separator grid.

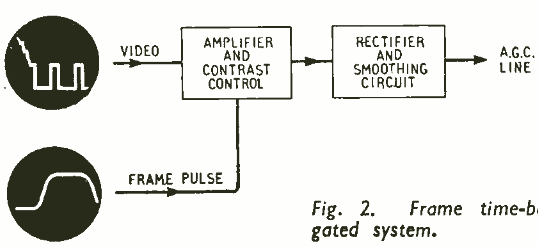


Fig. 2. Frame time-base gated system.

Also, in order to cater for all likely ratios of Band-I to Band-III signals, the a.g.c. should have a large range of control over the gain of the receiver, say 60dB, and there should be no necessity for a pre-set sensitivity control. With a large control ratio such as this, care must be taken to delay the control on the r.f. stages relative to that on the i.f. stages, and then to proportion it correctly, if a good signal-to-noise ratio is to be maintained over the whole control range of the system. This necessitates a larger a.g.c. voltage than if no delay were used.

Moreover, in order to simplify the viewer's task in adjusting his receiver, the a.g.c. operation should be independent of other adjustments, for example, time-base locking.

It was with these points in mind that this new system was devised, but before describing it we will give a brief survey of the other methods at present in use and their shortcomings.

Commonly Used Systems.—The simplest form of a.g.c. uses the mean d.c. voltage developed as a result of diode action at the sync separator grid. The general arrangement is shown in Fig. 1. The contrast control usually operates by applying a positive bias to the a.g.c. control line, thereby cancelling part of the developed negative bias. A diode is included, termed a delay diode, and this clamps the control line to earth for signals below a certain level which is determined by the setting of the contrast control.

There are three objections to this system. The smoothing circuit must deal with the 50-c/s video and sync components, resulting in rather a long time constant. On pictures of small d.c. level, such as dark scenes, the a.g.c. voltage diminishes and there is a tendency for the background to show up because of the increased gain. This is particularly annoying in weak-signal areas where the background may already be rendered brighter than intended by the presence of noise on the signal. The third objection is that the available voltage from this system is inadequate to allow a delayed system of control on the r.f. stage.

* Ferguson Radio Corporation.

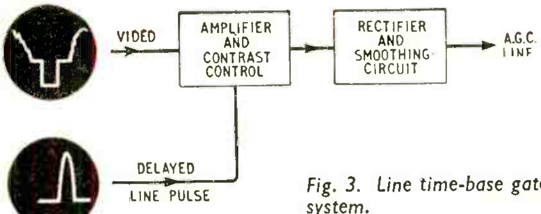


Fig. 3. Line time-base gated system.

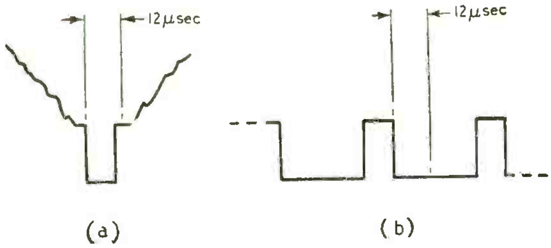


Fig. 4. Standard sync waveform showing (a) a line sync pulse and (b) part of frame sync pulses.

Fig 2. shows the basis of frame-pulse gated a.g.c. This method gates the valve producing the control voltage so that the output depends on the amplitude of the sync pulses during the frame fly-back, and since picture components do not occur during this period, the output is a true measure of the signal level. The contrast control may operate to determine the amount of pulse amplified by the a.g.c. valve. Because the gating frequency is so low, a long time-constant is required in the smoothing circuit. The frame hold control must be correctly set before the contrast to ensure that the gating waveform occurs at the right instants

For the line gated system shown in Fig. 3 the gating pulse is derived from the line time-base, and is delayed so that it operates the a.g.c. system during the "back porch" period of the line sync pulse. Since the back porch does not exist at the gating times during the frame pulses, i.e., approximately 12μsec after the negative-going edges in Fig. 4(b), there is a loss of a.g.c. during these periods, making it necessary to use a fairly long time-constant in the smoothing circuit. There is interaction between the line hold and contrast controls, because the system relies on the line time-base timing to obtain gating pulses at the correct instants. Usually these pulses are taken from the output circuit of the time-base, which does not operate for some time after the rest of the set has been switched on because of heating delay in the efficiency diode. Thus a protection circuit is required for this period to prevent overloading of the video circuits.

The "Sync-Gated" System.—The new form of a.g.c. system is basically a gated system, controlling the amplitude of the signal during the "back porch" of the line sync pulse, but the gating pulse is derived from the sync pulse itself rather than from the time-base, thus overcoming the difficulties experienced with some of the other systems as a result of the interdependence of "hold" and contrast controls. Reference to Fig. 4, showing the standard 405-line television synchronizing waveform, will explain the principle of the system. If this waveform is examined it can be seen that there is always a period of black level immediately following the positive-going edge of a sync pulse, whether it be a line or a frame pulse. Hence, a short-duration pulse derived from this edge and delayed slightly so that it occurs a microsecond or two after the edge, would form a suitable gating pulse for an a.g.c. system.

This is the basis of the new arrangement, the required gating pulse being obtained simply by differentiating the sync pulse and making use of the positive half of the waveform so obtained. This pulse is then added to the video waveform, the total amplitude being equal to the sum of the original pulse and the "back porch" level of the video signal (see Fig. 5). This total amplitude is made always to exceed the peak video amplitude and is passed through an amplifier, the pulses appearing at the anode of the amplifier being peak-rectified and used as a.g.c. voltage.

A very important feature is that the pulses are still present during the frame sync intervals—in fact they occur at twice the line frequency during this period—and so the considerable fall in a.g.c. voltage which occurs with line time-base gated systems during the frame sync interval is replaced by a small increase in voltage which can, however, be kept to a minimum by operating the rectifier under, as nearly as possible, peak rectifying conditions. In actual practice it has been found that, for a given percentage of 50-c/s ripple on the a.g.c. line, a considerably shorter a.g.c. time-constant can be used with this system than with the line time-base gated system, thus improv-

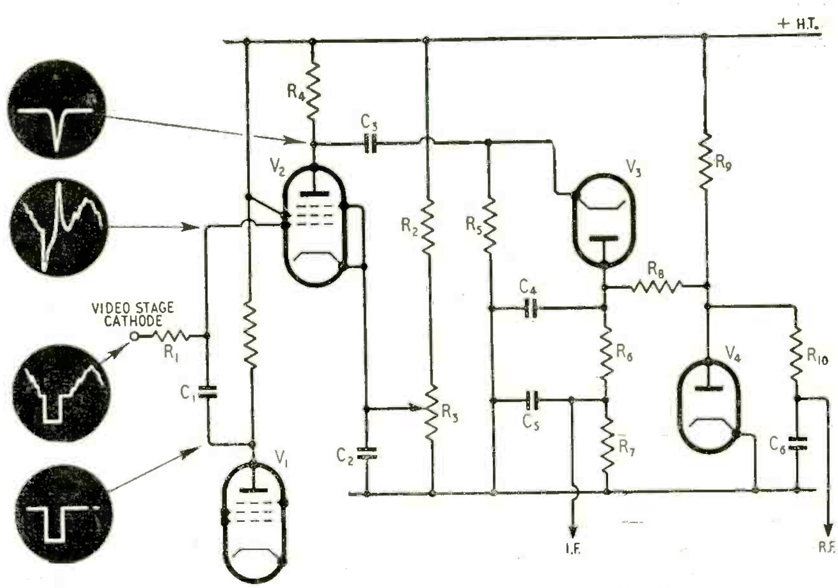


Fig. 5. Circuit of the new sync-pulse gated system.

ing control of rapid fading such as aircraft flutter.

It is, of course, essential that the sync separator in the receiver is capable of maintaining its output sync pulse constant in amplitude and speed over an adequate range of contrast settings, otherwise a positive feedback loop will exist via the a.g.c. line, and low-frequency fluctuations will occur in the gain of the controlled stages of the receiver. In commercial receivers the sync separator usually limits inadequately below about 10 volts peak-to-peak video signal, with the result that these fluctuations may occur if the contrast control of the receiver is adjusted to give a video voltage of this order at the cathode (or grid) of the cathode-ray tube. This is not considered to be a very serious objection, since such an amplitude of video signal represents a picture of extremely low contrast on the average cathode-ray tube.

A practical circuit is shown in Fig. 5. The video waveform including sync pulses is taken from the video stage cathode and a differentiated pulse from the sync separator (V1) anode, formed by the short time-constant C_1R_1, is added to it at the grid of the a.g.c. amplifier V2. Since the cathode of the video stage is a low-impedance point, the amount of pulse fed back into the video amplifier is very small. The delay in the sync separator is sufficient to ensure that the positive part of the pulse lies over the back porch.

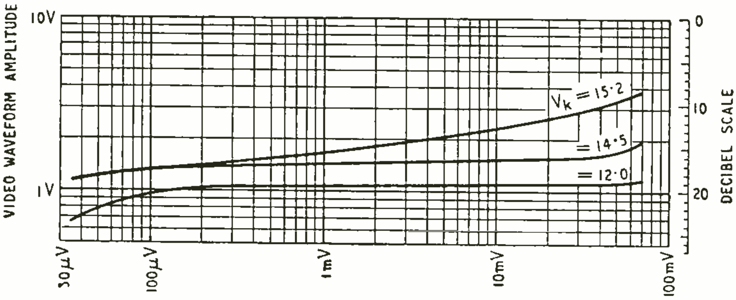
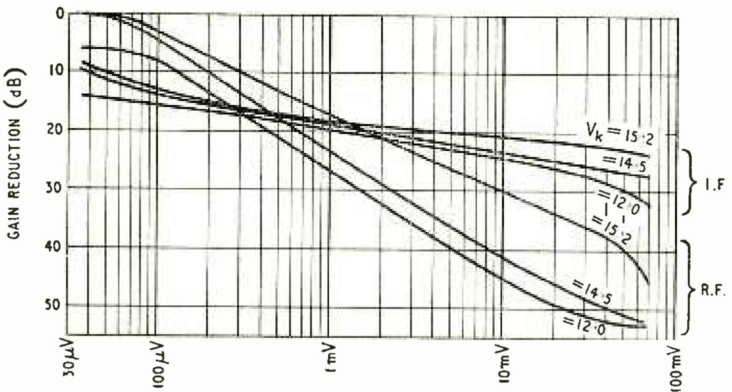


Fig. 6. A.G.C. curves for Ferguson Model 203T receiver with various settings of the contrast control. The video waveform amplitude is peak-to-peak (including sync) measured at the cathode of the video amplifier stage. It should be multiplied by 23 for the amplitude at the cathode-ray tube.

Fig. 7. A.G.C. curves for the 203T receiver showing the distribution of control between r.f. and i.f. stages.



The valve V1 is operated under very short grid-base conditions so that the pulse produced is constant in amplitude over a wide range of contrast, and this amplitude is sufficient to extend well beyond the peak-white level at the grid of V2. This valve is biased by the contrast control R_3 and resistor R_2 so that it conducts only on the tips of the pulses. Hence the output at the anode of V2 consists of pulses whose amplitude for any given contrast setting depends only on the back porch level and therefore the signal level.

These output pulses are coupled to the diode V3 circuit by C_3 and R_5. The diode load is split into R_6 and R_7, the tapping supplying bias to the vision i.f. stage. A delay network comprising R_8, R_9 and the diode V4 supplies bias to the r.f. stage. The capacitors C_4 and C_5 are small, so that a short time-constant exists on the control line of the vision i.f. stage. Since there is a small change in the a.g.c. voltage during the frame pulses, a longer time-constant is used for any stages common to vision and sound. Thus extra smoothing, R_{10} and C_6, is added for the r.f. stage.

The relative values of the resistors forming the delay system may be found in the following manner. If e_1 is the required i.f. stage bias at which control on the r.f. stage should commence and, under maximum signal conditions the i.f. stage bias should be e_2 when the r.f. stage bias is e_3 in order to avoid overload of the early receiver stages, then we may write:—

$$Ae_1 - Be_0 = 0$$

and

$$Ae_2 - Be_0 = e_3$$

where

$$A = \frac{R_6 + R_7}{R_7}$$

$$B = \frac{R_8}{R_8 + R_9}$$

$$e_0 = \text{h.t. voltage}$$

These equations yield:

$$A = \frac{e_3}{e_2 - e_1}$$

and

$$B = \frac{1}{e_0} \cdot \frac{e_1 e_3}{e_2 - e_1}$$

Curves showing the effectiveness of the system as applied to a complete receiver are given in Fig. 6 and it can be seen that for an average setting of the contrast control (the curve marked $V_k = 14.5$) a change of 60dB in input signal is reduced to only 2.5dB at the cathode-ray tube. At a higher contrast setting ($V_k = 15.2$) the control is not quite so good but even so a change of 60dB in input causes only 8dB change in video voltage.

Fig. 7 shows the way in which the control over the total receiver gain is divided between the r.f. and i.f. stages. This clearly demonstrates how the r.f. gain is maintained at a high level for weak signals in order to achieve a good signal-to-noise ratio, while with strong signals the majority of the gain reduction occurs in the r.f. stage in order to avoid overloading the mixer stage or first (uncontrolled) i.f. amplifier.

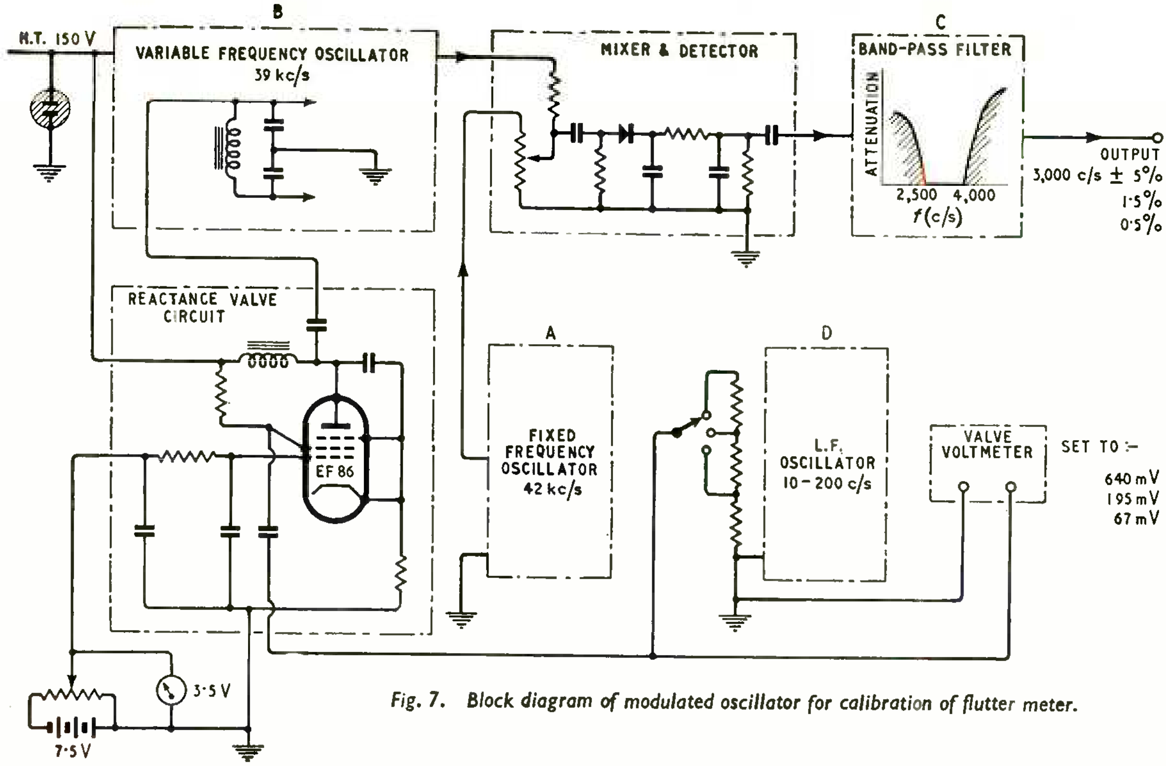


Fig. 7. Block diagram of modulated oscillator for calibration of flutter meter.

the relay of about 3 mA, does the armature of the relay close contacts c-c, shorting to earth the grid of the oscillator. Another pair of contacts b-b lights up a pilot bulb, indicating that the test signal is of approximately the right level. Accurate adjustment of level (to minimize a.m.) can be made by switching the output meter to the anode circuit of the limiter (point B), where the signal should be 3 volts, and setting the input potentiometer P (Fig. 2). This adjustment of level is recommended when making an ordinary test of flutter, and essential when frequency drift is checked. We shall return to this subject later.

Flutter Analysis. Flutter wave form is usually complex and irregular. It often happens that one frequency is predominant and it is desirable to estimate this frequency. Fig. 5 shows how this frequency may be found by using an external calibrated low-frequency generator. On the reduced flutter output (say 1/5 of f.s.d.) is superimposed about 20 V a.c. from the external generator, resulting in a deflection of the instrument to some point near the middle of the scale. Switching over to the external oscillator is carried out by switch S which simultaneously reduces the flutter level by introducing resistor R.

If now the frequency of the external generator is slowly changed from 10 to 200 c/s, the deflection will not change until one of the flutter frequencies approximates the external frequency. The needle of the instrument then indicates a slow beat with the search frequency. This is well known as the simplest method of analysing a complex wave, but in our case, a search often has to be repeated several times, as flutter usually has varying amplitude and it is easy to miss the beat frequency.

Frequency Drift. In tape recorders very slow frequency drift is sometimes experienced. This can be checked and measured by comparing the rectified 3,000-c/s carrier from the test oscillator and the played-back recorded note with the auxiliary meter of Fig. 4(b). Levels of both signals have to be identical and the following procedure in this test has to be observed (see Fig. 6). While testing, the level of the played-back note has to be adjusted by potentiometer P (Fig. 2) with button "a" depressed (output meter set to f.s.d.). Then, depressing buttons "b" and "a" simultaneously, the output from the oscillator is fed to the input socket of the flutter meter and f.s.d. adjusted by fine control of the attenuator. In this way both levels are set identically. Then with push buttons "a" and "b" off and recorded tone 3,000 c/s still going through, the reading should be noted on the microammeter (Fig. 4(b)). By depressing only button "b" the carrier from the oscillator is in turn measured. If both frequencies are the same (no frequency drift), both readings should be the same; the usual procedure is to make a note of the second reading (oscillator), switch back to the signal from the recorder and observe subsequent drift. The microammeter scale can be calibrated to read directly in cycles per second of drift.

Calibration of Flutter Meter. Although initial alignment can be made using a convention a.f. signal generator, calibration of gain requires the use of a flutter generator. For our purpose the flutter generator should produce a frequency-modulated 3,000 c/s carrier, with frequency deviation continuously controlled up 10%, at repetition rates within the limits 2-200 c/s.

As a general guide Fig. 7 gives a block circuit of the calibrating arrangements. This is basically a beat-frequency oscillator with a fixed frequency 42 kc/s supplied from oscillator A (small amplitude) and variable frequency from oscillator B (39 kc/s large amplitude). After mixing and detection the resulting beat note (3,000 c/s, frequency modulated) is passed through band-pass filter C. The chief purpose of this filter is to remove from the output traces of superimposed modulating frequency and to suppress higher frequencies derived from oscillators A and B. Frequency deviation is achieved by a reactance valve circuit in which deviation limits are controlled by the l.f. oscillator D (voltage measured by V.V.). In this case the reactance valve, with initial bias 3.5 V, would produce a change of frequency in oscillator B within the limits ±150 c/s with a modulating voltage of 640 mV r.m.s. Consequently the output would be 3,000 ±150 c/s—which represents 5% flutter (peak-to-peak). For deviations of 1.5 and 0.5%, 195 mV and 67 mV r.m.s. respectively were required from the modulator.

Commercial Literature

Junction Transistor Circuits for home construction using Mullard OC70 and OC71 types. Brochure giving basic circuit configurations, operating instructions, explanation of data, characteristic curves and various practical circuits from Mullard, Century House, Shaftesbury Avenue, London, W.C.2.

Wire-wound Potentiometers and rheostats, including ganged and concentric types. Specifications and mechanical details in an illustrated catalogue from the British Electric Resistance Company, Queensway, Enfield, Middlesex.

Amplifier Printed Circuit for the Osram "912" audio amplifier. Instructions for assembling the components on the printed circuit and details of a suitable chassis given in an illustrated technical bulletin from The Telegraph Condenser Company, North Acton, London, W.3.

Light-weight Flexible Cords for hearing-aids, headphones, microphones, etc. Table giving details of cores, coverings, resistances, current ratings and other information on the range produced by Amplivox (Industrial Products Division), 2, Bentinck Street, London, W.1.

U.H.F. Communications Receiver covering 150-500 Mc/s (a.m. and f.m.) in six positions of a miniature tuning turret, with sensitivity of 10 μV for 15-dB signal/noise ratio. Can be powered from batteries as well as mains, and facilities are provided for use as a test instrument. Illustrated leaflet on the Eddystone Model 770U from Stratton & Co., Alvechurch Road, Birmingham, 31.

Special-purpose American Valves.—A list giving type numbers and descriptions of the types available from Industro, 649, Broadway, New York 12, N.Y., U.S.A.

Aluminium Soldering Tool using a vibrating steel-wire brush in the centre of the soldering bit. Descriptive leaflet from the Belark Tool and Stamping Company, 130, Mount Street, London, W.1.

High-quality Audio Amplifier with 12 watts output, frequency response of 20 c/s-25 kc/s within 0.2 dB and total harmonic distortion of less than 0.1% at 10 W and 700 c/s. Disc record compensation and variable l.s. damping factor. Also a pre-amplifier control unit. Leaflet from R.C.A. Photophone, Lincoln Way, Windmill Road, Sunbury-on-Thames, Middlesex.

Gramophone Turntable Unit of "transcription" quality for three-speed operation, claimed to have no wow, flutter, rumble or hum induction. Descriptive leaflet from Woollett Sound and Wireless Equipment, Wells Park Road, London, S.E.26.

Distributor's List of products stocked and manufacturers. Available to trade, research and industrial organizations from Holiday and Hemmerdinger, 74-78, Hardman Street, Deansgate, Manchester, 3.

Plastic Extrusions for insulation purposes, mostly in P.V.C. Leaflet outlining manufacturing facilities available, from Creators, Plansel Works, Sheerwater, Woking, Surrey.

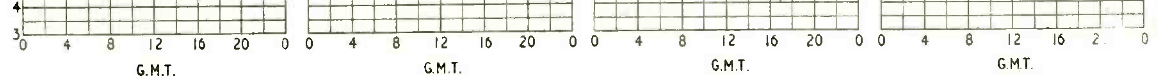
R.F. Induction Heaters, bench type, with continuously variable heat output over a 20:1 range. Two models available: 1 kW and 3 kW. Specification on a leaflet from Radio Heaters, Eastheath Avenue, Wokingham, Berks.

Transcription Gramophone Unit with speed continuously variable from above 78 r.p.m. to below 16 r.p.m. Also vertical-edge driving pulley claimed to eliminate rumble. Leaflet from The Goldring Manufacturing Company, 49-51A, de Beauvoir Road, London, N.1.

Multi-pole Changeover Relays; sealed types suitable for aircraft installations, with novel wiping action of contact surfaces and higher voltage contact blocks. New developments in Pullin relays described in a leaflet from Measuring Instruments, Electrin Works, Winchester Street, Acton, London, W.3.

Secondary Cell, 2-volt, for use with vibrator power supplies of portable equipment. Notable improvements in plastic container and combined gas vent and acid trap. Information from Chloride Batteries, Exide Works, Clifton Junction, Swinton, Manchester.

SHORT-WAVE CONDITIONS *Predictions for November*



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

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

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

— — — PREDICTED AVERAGE MAXIMUM USABLE FREQUENCY

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

Information Theory

Widening Fields of Application Discussed at London Conference

THE third symposium on information theory to be held in London* was housed this year at the Royal Institution. The change of address from the Institution of Electrical Engineers, where the last one was held, certainly reflected the different character of this year's proceedings, which seemed to have kicked away the ladder of mere technology by which information theory rose to fame. Whereas the I.E.E. symposium was mainly concerned with practical applications of Hartley's and Shannon's work and had a direct appeal to communications engineers, the Royal Institution offered such a miscellaneous collection of scientific subjects that any engineers present could have been forgiven for asking themselves what they were doing there at all. Welsh spelling rubbed shoulders with nerve mechanisms, randomizing machines with the cochlear nucleus and games strategy with optical transmission, not to mention statistics, translating machines, codes, linguistics, clerical operations and extra-sensory perception.

There were, however, a few topics that could be said to represent our own sphere, and one of particular interest was concerned with coding information to increase the efficiency of communications channels. This term "coding" is often used loosely to describe a process by which the signal is converted from one physical variable into another (for example, from amplitude changes to frequency changes, as in f.m.) without altering its essential structure or pattern. What "coding" should really mean is a process which takes into account the statistical nature of the signal, so that less time or signalling power is given to representations which occur frequently, and therefore convey little information, and more to those which occur infrequently and give a good deal of information. A familiar example is the Morse code, where the letters which have the greatest probability of occurring in English text, like E and T, are given the shortest symbols.

A good deal of research is being done to apply this kind of coding principle, not only to "telegraphic" signals but to continuous ones like speech and television waveforms, in order to reduce the bandwidth or signalling power required in communications channels. It becomes particularly valuable when the "conditional probabilities" are taken into account. For example, in English text when the letter Q occurs it is almost certain to be followed by U, so that when the U actually comes up in these particular circumstances it conveys very little information and should be given less time or signalling power than it normally gets. Again, this principle can be applied to signals of a continuous nature.

A more recent offshoot of this work has been on special codes for detecting and correcting errors, and these are used mostly for "telegraphic" signals such as the trains of pulses in digital computers or telephone dialling systems and, of course, in telegraphy itself. The term "errors" here refers to changes in the signals caused by noise, intermittent faults or any other kind of interference with the transmission channel. In a digital computer, for example, a single noise pulse added to a train of binary digit pulses representing a number could make a difference of thousands or millions in the result of a calculation. The general principle of detecting and correcting such errors is to add some extra symbols to the "message" to act as a check on the accuracy of what is received, rather like the tally of words sent in a telegram. This entails some redundancy in the code and its efficiency is thereby reduced, so the aim of the "information theorists" is to design effective codes with minimum redundancy. The methods used for detecting the errors are complex, but in the binary system of signalling (with which the codes are mostly concerned) the process of correction is simplicity itself. Since there are only two symbols used, 0 and 1, once it has been determined that an error exists at a particular position in a train of digit pulses it is only necessary to reverse the digit in that position from 0 to 1 or from 1 to 0 as the case may be.

Speech Recognizing Machine

Papers concerned with various aspects of binary coding at the symposium were "The Synthesis of Linear Sequential Coding Networks" by D. A. Huffman, "A General Class of Codes and their Physical Realization" by A. E. Laemmel and "Coding for Noisy Channels" by P. Elias. The notion of error correction and that of "conditional probabilities" mentioned above also came into an interesting description by D. B. Fry and P. Denes of their experimental work in building an automatic speech recognizer—a machine that will produce typewritten versions of words spoken into it. The main problem here is that a machine cannot recognize words simply by their acoustical properties, which vary considerably with pronunciation, intonation and quality of voice. This is also true of *homo sapiens*, of course. It is necessary for the machine, like the human being, to have a store of linguistic information to act as a check on the acoustical frequency patterns and modify them when they seem to have an improbable structure. In the recognizer described by Fry and Denes this is done on an elementary level by using the "conditional probabilities" with which certain sounds occur after other sounds in a given language.

First of all, the purely acoustical patterns are "recognized" by a series of filters, which divide up the frequency spectrum into adjacent bands. Most phonemes give rise to characteristic spectral patterns which can generally be identified by coincident peaks of energy in particular pairs of filters. The outputs of the various pairs of filters are multiplied together and this gives a series of voltage products which vary in relative magnitude as changes in the applied speech wave move the energy maxima from filter to filter. An electronic circuit then detects the greatest of these products and indicates the occurrence of the corresponding phoneme.

The linguistic information on "conditional probabilities" is stored in the form of slider adjustments on

* Organized by Dr. Colin Cherry, of Imperial College.

sets of potentiometers. Each set is associated with a particular phoneme and the various sliders give voltage outputs proportional to the probabilities of the other phonemes which may follow it. What happens in operation is that when a particular phoneme is recognized by the filter-pair system, say *i*, this information is stored in a corresponding memory circuit until the next phoneme occurs and then used to switch the voltage indicating the occurrence of this next phoneme to the *i* set of potentiometers. The "probability voltages" from the sliders are then sent to the filter-pair system, and here each phoneme acoustical output voltage is multiplied by its corresponding probability voltage. Thus the acoustical recognition of the phoneme following the *i* is biased or weighted according to the probability of its occurring in the language. So if the filter-pair system has a tendency to produce the largest voltage for a phoneme which is similar to the one spoken but not actually correct, the weighting by the probability voltages will most likely swing the balance and cause the correct acoustical output to have the largest voltage. This is then selected by the electronic circuit mentioned above and used to operate an electric typewriter.

Some interesting and amusing typewritten results were shown by Fry and Denes which clearly demonstrated the greater accuracy of recognition obtained with the aid of the store of linguistic information.

Applications of Computers

In one sense mechanical speech recognition can be regarded as a coding problem since the actual structure of the information is altered. A rather different type of coding, though again for transformation of language information, was described in a paper by A. D. Booth and J. P. Cleave—the "programming" of a digital computer to transcribe ordinary alphabetic text into Braille. The technique was similar to that outlined in the article on language translation in a recent issue* except that with Braille the transcription was in terms of individual letters and simple groups of letters (or simple words) called "contractions." There is not, however, a simple one-to-one correspondence between printed characters and the Braille signs, for the particular signs used depend upon the context. Transcription into contracted Braille, in fact, is almost as complex as translation into a foreign language, except that the words in real language are replaced by "letters" in Braille and the word groups or idioms by Braille letter groups.

Computing machines are also being used in another field of information theory to investigate the transmission of information in the animal (or human) nervous system, which can be regarded as a kind of communications network. The general idea is to organize the machines to imitate the external patterns of behaviour produced by the nervous system in the hope of throwing some light on the actual physiological mechanism of the system, which is very difficult to investigate by other means. One paper, by O. G. Selfridge, described the adaptation of a digital computer to give recognition of visual patterns. Here, there was no attempt to make the machine imitate the nervous structure directly—only its functions. Another paper, however, by W. K. Taylor, described a network more in the nature of an analogue computer which was built up from model neurons having electrical properties similar to those of living nerve cells and sensory receptors. Each model cell contained electronic circuitry using seven valves. Experiments were described in which the correct "physiological" response to a pattern of stimulation could be "learnt by association" by the network.

* "Language Translation by Electronics," by J. P. Cleave and B. Zacharov, *Wireless World*, September, 1955.

In particular the sense of hearing offers a challenge to information theory because of the complexity of the path from air to brain and because of its incredible sensitivity. It has been calculated that at the threshold of hearing the displacement of the eardrum is less than the diameter of a hydrogen molecule. If the total energy available is divided by the observed number of sensory cells in the inner ear it turns out that the signal is well down into the thermal noise level. This results in a constant random "firing" of nerve threads which is to some extent ordered by interconnection, feedback and autocorrelation in the presence of even the weakest sound stimulus.

A detailed investigation of the function of the cochlear nucleus, reported by J. T. Allanson and I. C. Whitfield, confirms this view and shows that the pattern of response to a pure tone is modified from a Gaussian or humped-back distribution of activity in the ingoing fibres, to a steep-sided, flat-topped band-pass response in the outgoing fibres. This sharpening of the region of neural activity is thought to account for the observed degree of discrimination of pitch, and it was suggested that the width of the "pass-band" might prove to be related to the perception of intensity. Weight is lent to this hypothesis by the known dependence of subjective pitch on intensity.

Frequency analysis lies at the root of all theories of hearing and a comprehensive survey of the present state of our knowledge was made by J. C. R. Licklider who pointed out that the "place" theories of Helmholtz and Bekesy, which identify specific regions of excitation in the cochlea with different frequencies, were insufficient to explain the subjective recognition of a low-pitched fundamental residue when the ear is stimulated by high harmonics only of that fundamental. Schouten's work on this subject had made it clear that the low pitch remained after any combination tone due to non-linearity in the ear had been balanced out by a variable-phase search tone.

An alternative demonstration was given by Prof. Licklider in which short bursts of a sine-wave fundamental were interspersed with tones consisting of the higher harmonics only. A random low-frequency masking noise was then introduced, which completely suppressed the sine wave but left the sensation of low pitch from the harmonics untouched.

These results could not be explained by any existing simple "place" theory. There was the possibility that a transformation from time to place might occur in the cochlear nucleus or at high levels in the path from ear to brain, and the main part of his paper was devoted to a detailed description of a "triplex" mechanism which might fit the facts so far observed.

It seems, then, that the principal role of information theory in all these different fields has been to throw a new light on old problems. Channels of communication have been found to exist in situations which were never considered in this way before. At the same time one cannot escape the conclusion that many of the researches described at the symposium might have gone on quite successfully without information theory! However, the world of communications must take it as a compliment from the rest of science that such attention is being paid to the subject.

Measurement of "Wow" and "Flutter"

Basic Circuitry of a Test Instrument

By

O. E. DZIERZYNSKI

BEFORE the subject of measurement can be considered it is necessary to form a clear picture of what exactly is meant by "wow" and "flutter," as misunderstandings often arise where terminology is concerned.

Wow or flutter is a periodic or non-periodic frequency deviation (occurring mostly when reproducing from magnetic tape or disc records) expressed as a percentage of the mean frequency. For example, if a recorded signal of 3,000 c/s varied on reproduction between 2,970 and 3,030 c/s, wow or flutter in this case would be:

$$\frac{3{,}030-3{,}000}{3{,}000} \cdot 100 = \frac{3{,}000-2{,}970}{3{,}000} \cdot 100 = \pm 1\%$$

We are here dealing with peak-to-peak values, as we should in the case of slow deviations, but for higher rates the mean value of frequency deviation is usually considered. Consequently, if flutter were given as, say, 1% without saying that this referred to peak-to-peak deviation, it would be safer to take the maximum frequency range as being approximately ±1.5%, assuming that the waveform is nearly sinusoidal.

A second term (entirely different in meaning from percentage wow or flutter) is wow/flutter *frequency*. As we mentioned previously, change of frequency may often occur in a periodic way. This period of frequency variation can be from a few cycles/sec (or even less) up to a few hundred cycles/sec, and can be divided into two ranges, i.e.: "wow"—corresponding to frequencies within the limits 0-20 c/s and "flutter"—covering all frequencies between 20 and 200 c/s. Wow itself could be divided again into a "very slow" wow, 0.2 c/s* (not so audible), and "normal" wow within the limits 2-20 c/s. It is significant that "very slow" and "normal" wow and flutter are different not only audibly but also from the measuring equipment point of view; a "very slow" wow has to be measured by different circuitry.

Choice of Carrier (Test) Frequency. Frequency variation when occurring with the same percentage deviation over a wide range of carrier frequencies has different audible effects depending upon carrier frequency, rate of change (wow/flutter frequency) and individual hearing characteristics. It can be assumed, however, that a carrier frequency lying between 2,000-5,000 c/s is most vulnerable to wow and flutter and consequently 3,000 c/s has been chosen internationally as the test frequency.

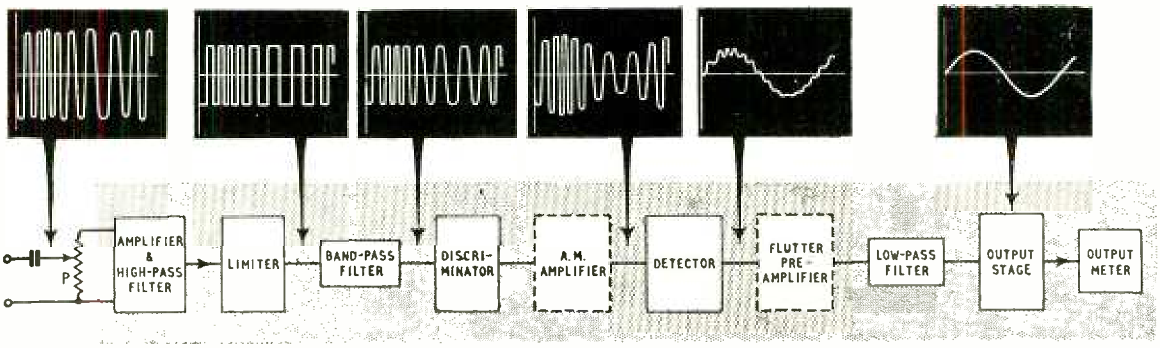
Purpose of Wow/Flutter Measurements. There are two main reasons for this sort of measurement. First, to check the percentage of frequency variation to ensure that it does not exceed the allowed limit; and, if this is the case, to make necessary adjustments and repairs in the apparatus under test. Secondly, to establish an objective figure of merit which can be used also for equipment with frequency deviations which are difficult of detection by the average human ear. For instance it can be generally assumed that equipment with w/f (wow or flutter) higher than 0.5% represents poor performance and below 0.05% is associated with best-quality reproducers. As flutter meters are most used for fault finding, it often happens that not only percentage of w/f has to be checked, but also w/f frequency estimated—the chief reason being to find the cause of the trouble. This certainly complicates matters, particularly as the flutter waveform is generally of a complex nature. We shall return to this subject later in the article.

Principle of Flutter Meter. Fig. 1 is a block diagram of a w/f analyser. Flutter phenomena are similar to frequency modulation in r.f. circuits. Consequently the flutter meter has similar stages to those of a f.m. receiver, the chief difference being, of course, an audio-frequency carrier (3,000 c/s) and very low deviation. This latter factor has an important influence on the design of the limiter and output stages.

Let us consider stage-by-stage how a flutter meter works. The signal of nominal frequency 3,000 c/s, from the output of, say, a tape recorder, is fed through an amplifier to a limiter. The purpose of the limiter is to reduce the minimum amplitude

*British Standard 1988:1953 recommends the use of the term "drift" for deviation of frequency "below about 0.1 cycles per sec." [Editor.]

Fig. 1. Block schematic diagram of wow/flutter meter.



modulation, and to provide a reasonably constant input to the discriminator.

The limiter is followed by a band-pass filter which restores the sinusoidal waveform which was lost in the limiter stage. The level here is of the order of 100-500 mV.

The discriminator is designed as an amplifier with a linear (or close to it) characteristic of gain with frequency within the limits 2,700-3,300 c/s. An ordinary parallel-tuned L-C circuit in the anode circuit of the discriminator is good enough for this purpose and this circuit should be tuned to approximately 3,400 c/s (peak) (see Fig. 4). Under these conditions, the discriminator amplifier would have only about half of the available gain from the carrier of 3,000 c/s (working on the slope of resonant curve).

If a frequency-modulated 3,000 c/s signal is applied to the grid of V3 the output from the anode will be an amplitude-modulated carrier (incidentally still partly frequency modulated). This produces an amplitude-modulated carrier which should, if necessary, be amplified to at least 10 V before detection.

Diode detection is usually employed and the output from it, after removal of the d.c. component, contains the w/f frequency plus the remains of the carrier and carrier-harmonic frequencies.

As the flutter component is often a matter of only a few millivolts, a low-frequency amplifier has to be introduced between detector and a.c. output meter. The gain of this amplifier is of the order of 35-40 dB to ensure that the a.c. output meter (about 10 V f.s.d.) is working on the linear part of its scale.

A low-pass filter (cut-off frequency about 300 c/s) is often inserted between detector and output meter, to reduce carrier-frequency components.

As we shall see later, provision can be made to measure very low frequency wow (or frequency drift) by inserting a d.c. microammeter in series with the diode load resistor R_L (Fig. 4 (a)). Variations of frequency will be followed by the instrument pointer, provided that they are slow compared with its natural period, i.e., below about 2 c/s.

Circuit Details

Input Stage. Fig. 2 gives more details of the input circuit. The reproduced test signal of 3,000 c/s is passed through the pre-amplifier V1A, cathode follower V1B and high-pass filter. All lower frequencies (including hum) present in the output of the tape recorder are removed, as they can otherwise affect the final reading of the output meter. The purpose of the cathode follower is to match the low input impedance of the filter (3,000 ohms) to the high output impedance of the pre-amplifier. The choice of a low filter impedance has the advantage of making the design of the filter much easier, also of reducing hum pick-up at the input of the limiter.

Limiter. Two types of limiter circuit were considered during the development of the meter described in this article. The first employed a ECC81 working as an overloaded cascade amplifier with additional clipping action by diodes. A square valve was ob-

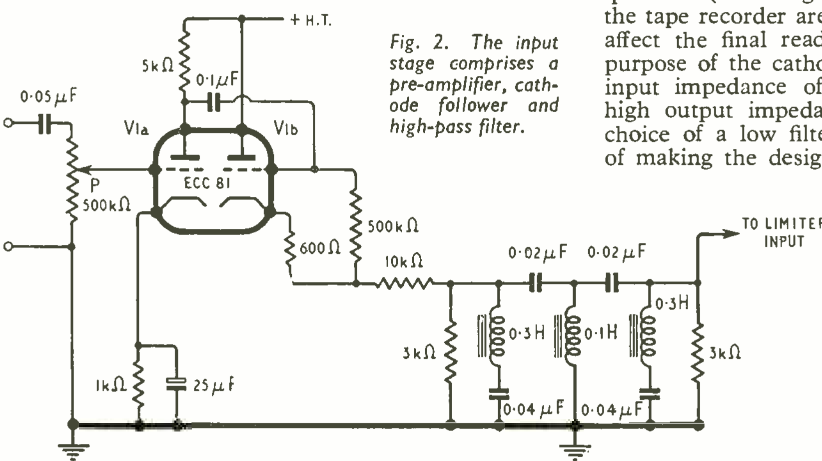


Fig. 2. The input stage comprises a pre-amplifier, cathode follower and high-pass filter.

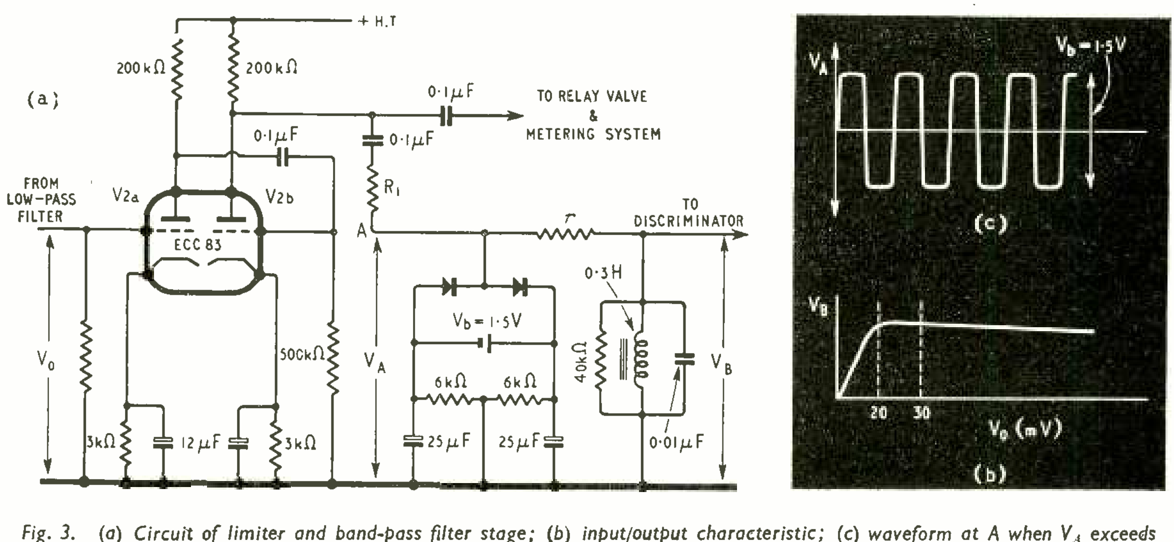


Fig. 3. (a) Circuit of limiter and band-pass filter stage; (b) input/output characteristic; (c) waveform at A when V_A exceeds the bias V_b.

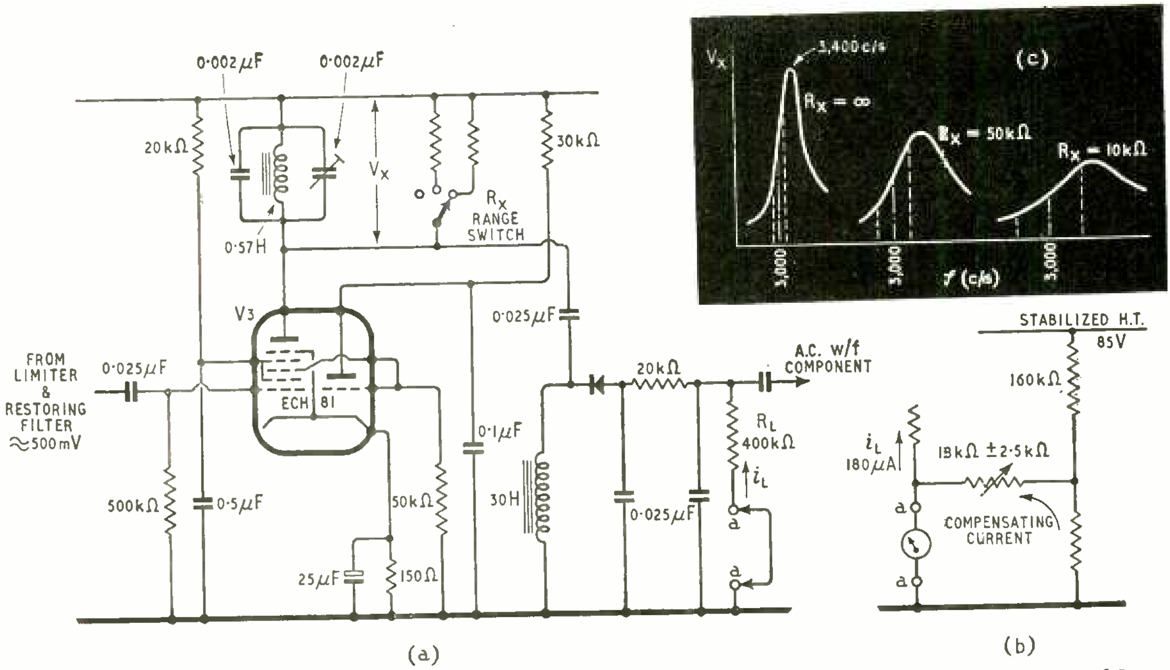


Fig. 4. (a) Discriminator and detector circuit; (b) Microammeter connections for measurement of drift; (c) Effect of R_x on slope of discriminator curve.

tained of peak value 75 V, approximately constant for all values of input voltages within the limits 80 mV-10 V. Fig. 3 (a) shows the second system which was finally adopted. Two negatively biased diodes are fed symmetrically with the a.c. signal through resistor R_1. At A the waveform is sinusoidal until the peak value of the signal exceeds the bias when the output takes the form shown in Fig. 3 (c). The amplitude remains substantially the same for inputs varying within similar limits to those quoted for the first system.

Band-pass (Sine-wave Restoring) Filter. Several systems have been considered and for simplicity and efficiency a single tuned circuit was chosen fed by resistor *r*. Damping of this tuned circuit had to be chosen very carefully, as sidebands within the limits 3,000±200 c/s had to be passed without appreciable attenuation. At the same time attenuation of the second and third harmonics (6,000 and 9,000 c/s) should be 20 dB at least. Fig. 3 (b) represents the limiter and filter characteristic, i.e., how the output of this stage depends upon input. There is a broad maximum for the input values 20-30 mV and it is clear that the optimum input for minimum amplitude modulation is about 25 mV.

Discriminator and Detector. Any r.f. pentode with sufficient gain could be employed for the discriminator, which is coupled to the detector stage. In the circuit of Fig. 4(a) the discriminator is the heptode section of an ECH81, which is of the variable mu-type

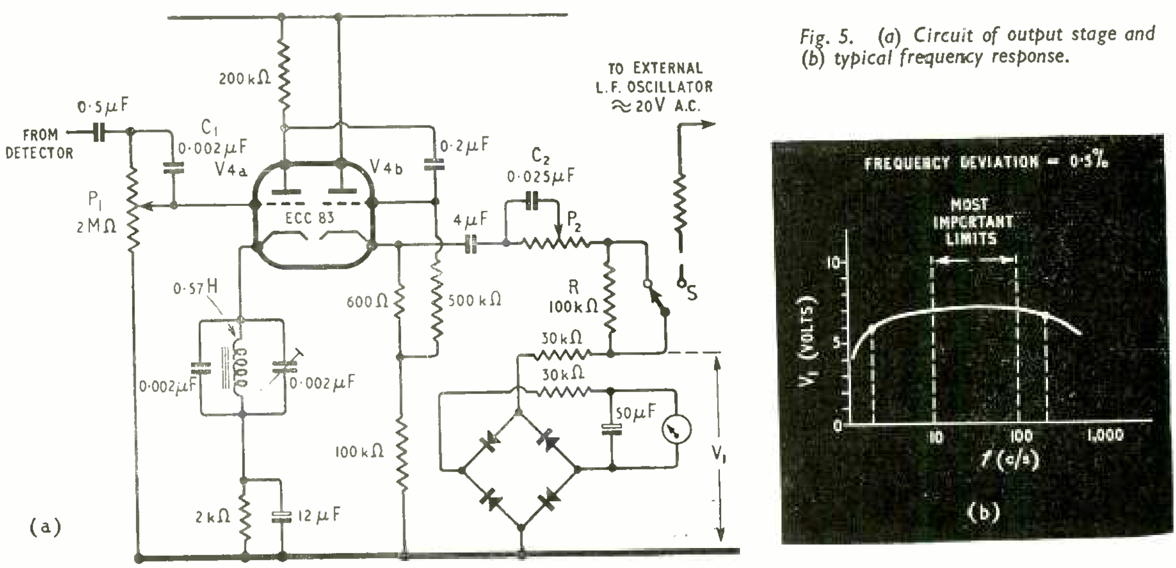


Fig. 5. (a) Circuit of output stage and (b) typical frequency response.

To stabilize the gain the triode section is connected to the h.t. to increase the cathode current so that a lower value of cathode bias resistor can be used.

It is important that the slope of the resonance curve should be sufficient to produce about 1 volt of flutter frequency across the detector load R_L for an input to the grid of V3 of about 500 mV with a frequency deviation of 0.5% (of 3,000 c/s). By shunting the resonant circuit (R_x) it is possible to reduce the discriminator efficiency very considerably. In this way it is possible to obtain a change-over to different ranges (see Fig. 4(c)). In this particular case resistors of 45 kΩ and 12 kΩ would cause a reduction of slope of 3 and 10 times respectively, while 1 volt a.c. of detector output could still be obtained from frequency variations of 1.5% and 5% respectively (with a signal of 500 mV fed to the discriminator grid). It will be seen from Fig. 4(c) that the value of rectified carrier current i_L) will be different in each range.

Very slow wow is measured with a microammeter (Fig. 4(b)) inserted in the detector load circuit. With a load resistor of 0.25 MΩ current i_L is approximately 180 μA, and a frequency change of ±0.5% would give a current change of approximately ±5 μA. Employing a meter with f.s.d. 100 μA, it is possible to compensate 130 μA from an external source to obtain neutral indication exactly in the middle of the scale. If the scale is calibrated in cycles, peak-to-peak measurement of the slow swing can be made. This method has the advantage that large slow variation of frequency can be measured, without range-changing facilities, as, even with wow up to ±5%, movement of the needle would be within the limits of the scale.

Output stage. As explained previously, a low-frequency amplifier and filter for carrier components must be included in the last stage of the flutter meter. Fig. 5 shows how this problem was solved in a simple and satisfactory way. The first half of the ECC83 is a R-C amplifier while the second triode serves as an output cathode follower feeding the output meter through a special network. A cathode rejector circuit tuned to 3,000 c/s was employed to reduce any remaining carrier signal (it was found that second and third harmonics were negligible at this point in the circuit).

The frequency response of the amplifier was given a strong lift towards 200 c/s (pre-set potentiometers P_1, P_2; condensers C_1, C_2) to compensate considerable loss of "higher" frequencies (in a band 5-200 c/s) through attenuation of sidebands in the discriminator circuit and smoothing capacitances in the detector circuit. The resulting frequency response (Fig. 5(b)) is more or less uniform: there is some loss at frequencies between 100-200 c/s and 5-10 c/s, but experience shows that the most important flutter frequencies are within the limits 10-100 c/s.

Oscillator and Ancillary Circuits. In Fig. 6 the EF86 is a stabilized 3,000-c/s oscillator with one half of the ECC81 as a buffer valve, while the second half works as a relay valve (see later). There are also some facilities for setting the exact level and for analysing flutter frequency contents. The oscillator circuit is a conventional Colpitts electron-coupled oscillator with automatic limitation of amplitude (see *Wireless World*, March 1954, p.110). The output is fed to a capacity attenuator which is used to maintain good waveform on lower ranges. Output voltages are in decade steps ranging from 1 mV to 1 V.

The second section of the ECC81 (V6b) is used as a relay valve. It is found that the oscillator, unless well screened, introduces a beat note with the played-back signal which upsets the accuracy of measurement. Consequently, it was arranged that while the recorded signal is played back, the oscillator is automatically switched off. This was achieved by applying a positive bias to the grid of the relay valve, this bias being derived from rectification of the 3,000 c/s played-back (fed from anode circuit V2b—see Fig. 3(a)). Only when signal is being passed through the limiter of sufficient level to give an anode current in

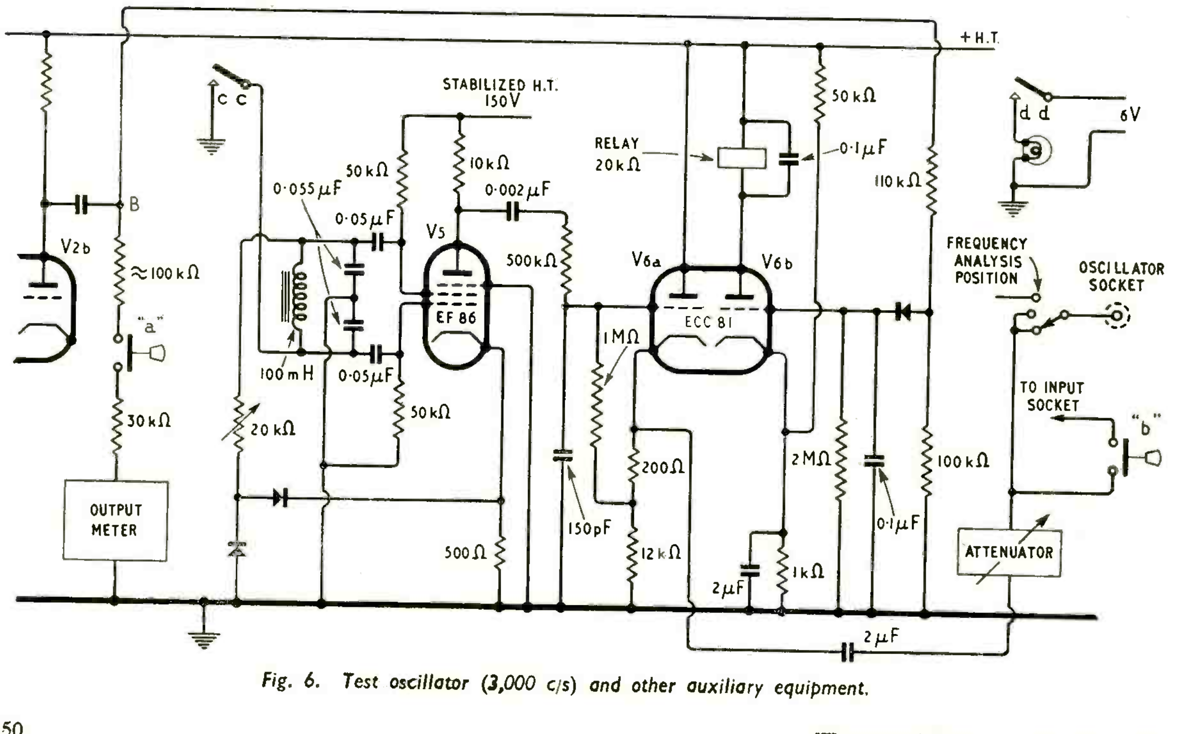


Fig. 6. Test oscillator (3,000 c/s) and other auxiliary equipment.

Polarization of Waves

By "CATHODE RAY"

What it Means and How it Can be Used

I HAVE a feeling that wave polarization is one of those things that the non-specialist tends to regard as too difficult to be worth trying to understand. When he comes across the news—as he may easily do nowadays—that radar is being rendered more effective by the use of circularly or elliptically polarized waves, does he have a clear picture of what this means? Or is there a certain amount of mental haze?

Many explanations of the polarization of radio waves conveniently assume that polarization of light is already understood. But so far as we are concerned it will probably be easier to understand the polarization of light in terms of polarization of radio waves, rather than vice versa. So I shall assume only a reasonable basis of radio, and then anybody who does happen to know about optical polarization will be able to amuse himself by looking out for the analogies.

First of all, then, let us refresh our memories about the main features of radio waves.

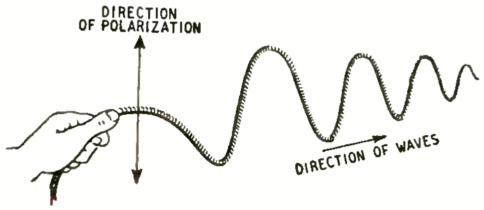


Fig. 1. Time-honoured procedure for generating transverse rope waves, in this case vertically polarized.

Unlike sound waves, they are transverse waves. That is to say, they consist of vibrations or alternations *across* the direction in which they are travelling. So they can be pictured quite aptly by the juvenile pastime of waving a long outstretched rope from side to side or up and down (Fig. 1). This process causes waves to travel along the rope—in spite of the fact that the movement which causes them is at right-angles to that direction. These rope waves could be called positional waves, because the thing that alternates is the position of each bit of the rope. If the rope's end is waved up and down, the position of that and every other bit of the rope alternates vertically and the resulting waves could be described as vertically polarized. If it is waved from side to side, they are horizontally polarized. The meaning of polarization is as easy as that!

The corresponding thing about radio waves is a little less easy, because it can't actually be seen. Moreover, in radio waves two things are alternating at once—electric field and magnetic field—both of them across the path of the wave, but at right angles to one another (Fig. 2). So although even the most perverse scientist could hardly refer to the polarization of his son's up-and-down rope wave as other than vertical, there is room for difference of opinion on what constitutes a vertically polarized radio wave. And where there is room for difference of opinion in scientific terminology, believe me, full advantage is almost invariably taken of it, to the confusion of all concerned. This case is no exception. In defining the direction of polarization there is a natural choice between two alternatives: making it the same as the direction of the electric field or of the magnetic field. Which has been chosen? *Both*! Electric for radio waves and magnetic for light waves, though radio and light are identically the same things except for frequency!

We radio people can argue, in favour of our choice, that it is so convenient to be able to say that a vertical dipole radiates and receives vertically polarized waves. The optical types, on the other hand, can retort that they were first in the field (even before anyone realized that there *was* a field!) and how could Mr. E. T. Malus (who invented "polarization") have foreseen in 1808 what TV fans would find convenient in 1955, and that it would have anything to do with the peculiar optical effects he was noticing in crystals of Iceland spar?

Anyway, from now on let us simplify matters by taking the "field" of radio waves to mean their electric field. Although we know the magnetic field is there too, for the present purpose we can leave it out of account.

Unlike generators of light—commonly called lights—generators of radio waves usually start the waves off with a definite direction of polarization. Although we have mentioned only two varieties—vertical and horizontal—because these are the only two in popular use, the angle of polarization can, of course, be anything between these two extremes.

Now because an electric field is invisible, the direction of its polarization is not obvious—unless perhaps one is within sight of the aerial responsible for it. But by connecting an alternating voltage between the top and bottom ("Y") deflection plates of a cathode-ray tube, so as to set up a vertical alternating electric field between them, the direction of that field is shown as clearly as could be by the vertical trace on the face of the tube, as in Fig. 3(a). Connecting instead to the "X" plates gives a horizontal line, as at (b). Any intermediate direction can be obtained by turning the

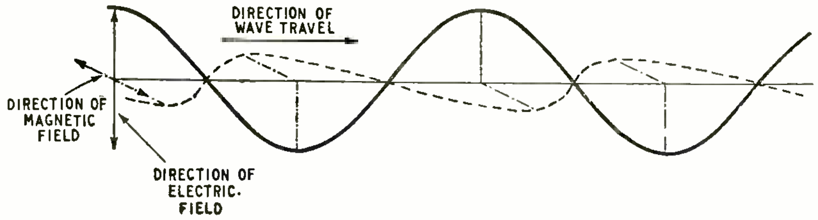


Fig. 2. In a radio wave two things are alternating at the same time, at right angles to one another and to the direction of travel. It is customary to regard the direction of polarization as that of the electric field. The magnetic field in this diagram is supposed to be at right angles to the paper.

tube around so that the direction between the plates in use is neither vertical nor horizontal.

But users of oscilloscopes will know full well that there is an alternative method of getting an oblique direction, without shifting the tube. If equal voltages are applied simultaneously to both pairs of plates the line appears at an angle of 45°, (c) or (d) according to which "X" plate is connected to the top "Y" plate. The vertical and horizontal fields combine to cause a single diagonal field. And conversely this—or any other—single field can for purposes of calculation be imagined as split up into two fields at right angles to one another—resolved into its orthogonal components, to put it technically. If one wants the angle to be something other than 45°, it can easily be done by making the vertical and horizontal components unequal.

In the same way, diagonally polarized radio waves could be produced by combining vertical and horizontal waves. But seeing that the same result can be achieved much more simply by mounting a single aerial at the appropriate angle, why should one want to? Well, supposing one wanted to vary the polarization, it might be easier to do it by an electrical control than by moving the aerial itself. To be honest, however, my only reason for introducing this idea was as an intermediate step in the argument. When I said that alternating voltages were applied *simultaneously* to the two pairs of deflectors, I meant to imply that they were in phase. But suppose next that we insert

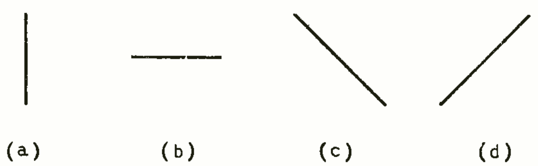


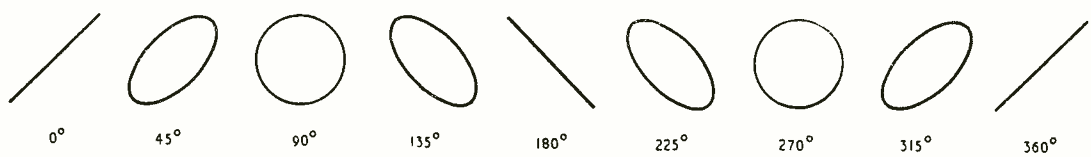
Fig. 3. Oscilloscope traces when a single alternating voltage is connected in phase to one or both pairs of deflector plates.

Fig. 4. Traces when the same alternating voltage is connected to both pairs of deflection plates, but with a variable phase delay in the connection to one of them.

—are elliptical. Even when the phase difference is exactly 90° (quarter of a cycle or wavelength) the polarization is not necessarily circular; it is only so if the two components are exactly equal. When they are unequal, the polarization is horizontally or vertically elliptical, as at Fig. 5(a) and (b). And having studied the matter so far you will probably be the first to guess that a combination of unequal components with other phase differences yields ellipses at all sorts of angles, such as Fig. 5(c) and (d).

The full possibilities have even yet not been seen. The reason is that at any frequency above a very few cycles per second the eye sees a complete trace on the oscilloscope screen, whereas in fact there is only a single spot moving around it. There are two ways it can move around—clockwise and anti-clockwise—and only when the frequency is very low indeed can these be distinguished. But the two directions exist, whatever the frequency; and so do these two varieties of any elliptical polarization of waves. The difference between the two depends on which component is delayed relative to the other.

Another thing to remember about the oscilloscope picture is that it represents no more than a cross-section of a radio wave. It is a very valuable representation, nevertheless, because it shows so clearly the significance of terms such as "linear polarization," "circular polarization," and "elliptical polarization." (By the way, the first two are often regarded as special cases of elliptical polarization.) But if now we are sure that all is clear so far, let us pass on from a wave marking time, as it were, in two dimensions, and give it the order "quick march"—at rather more than Army speed, say 186,000 miles per second. If the polarization is vertical, the oscillograph spot ceases to move up and down across the face of the tube and shoots out to meet us at that speed. Stepping smartly to one side to avoid it, we catch a glimpse of it broadside on; the combination of the up-and-down and the forward movement results in the familiar wave shape, Fig. 2. The spot is not now confined to a vertical *line*, but moves in a vertical *plane*; that is why the wave it represents is often called plane polarized (instead of linearly polarized), especially by optical characters.



a variable phase delay in the connection to one pair. When the delay is zero the results are as already shown in Fig. 3. Shifting the phase causes the diagonal line to open out into an ellipse, then into a circle, then into an ellipse sloping the other way, and so on, as shown in the examples in Fig. 4, which are taken at intervals of 45° phase difference. At 360°, or one whole cycle, we are back at the starting point and the whole thing begins again

This shows us that if we combined two sets of radio waves, one polarized vertically and the other horizontally, we could get other kinds of polarization than diagonal by introducing a phase difference between them. It should surprise nobody to learn that the kind of polarization that results when the phase difference is 90° (or any odd multiple thereof) is called circular, and all the others—except the special cases at 0°, 180°, etc., which are called linear

Of course a radio wave doesn't consist of a travelling spot; the spot is just something to help us to visualize a rapidly moving wavelike pattern of electric field. We can (I hope) easily see that a circularly polarized wave is represented by a corkscrew path moving forward in such a way that it traces out a cylinder. If we can't see this, then perhaps we had better take the clothes line out into the back garden and turn one end rapidly round in a circle at right angles to its length. Then, if we can still face the comments of the family and/or the neighbours, we might care to demonstrate the flattened corkscrew-cylinder of elliptical polarization.

But what, you may ask, is the practical outcome of all this? The wayfaring man, though a fool, can see that some short-wave radio aerials are horizontal and some are vertical. If not quite a fool, he might wonder why. We, with our knowledge of radio and

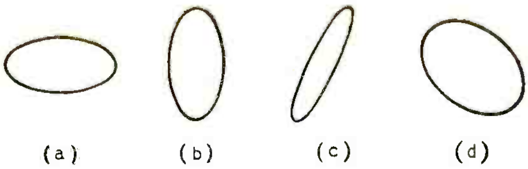


Fig. 5. Traces resulting from unequal voltages; in (a) and (b) they are 90° out of phase, and in (c) and (d) have other phase differences.

now of polarization, may be quick to guess one reason, especially if we are familiar with the optical analogy of crossed Nicol prisms or Polaroid sheets. Reception of a vertically polarized wave is a maximum when the receiving dipole is vertical, and decreases to zero as it is turned horizontal. So it would appear that this supplies a method of completely separating two transmissions on the same wavelength. In practice it doesn't usually work out quite perfectly, but it does give a very useful degree of discrimination, which presumably is why the B.B.C. uses both vertical and horizontal on the same television channels.

The reason why discrimination is seldom perfect, and the reason why for some purposes vertical polarization is chosen and for others horizontal, are bound up together, and are due to the fact (familiar to optical students) that polarization is affected by the things that happen to it on the journey of life—transmission, reflection, refraction, and so on. For instance, in some circumstances vertically polarized waves are reflected less from the surface of the sea than are horizontally polarized waves. One of the troubles in certain kinds of radar is that the "targets" one wants to detect are liable to be concealed by reflections from the sea. This is the sort of thing that must be taken into acount when choosing which polarization to adopt for any particular system. But it is not always easy to make a quick decision, for the influence of polarization on wave behaviour is a very complicated subject in practice, necessitating a vast amount of experiment under working conditions.

Just now there is a good deal of interest in adopting circular polarization instead of linear, and I'm going to use the rest of the space explaining why.

The fact that an aerial arranged for, say, horizontal polarization is "blind" to vertically polarized waves, which is useful if one wants to separate two transmissions on the same frequency, is a disadvantage if one wants to receive signals on that frequency whatever their angle of polarization. True, an aerial at 45° would be equally responsive to horizontal and vertical waves—the loss as compared with a perfectly aligned aerial would be, as you have probably already worked out, nearly 30 per cent, or 3dB—but it would be totally unresponsive to waves polarized at 135°. You might think that nobody would be so silly as to radiate waves at 135°, but what about banking aircraft? Apart from that, the vicissitudes of travel sometimes (as I have mentioned) play tricks with the polarization, so that a wave starting off at 90° may be nearer 135° by the time it arrives.

If the aerial were made in two parts, one vertical and the other horizontal, both joined to the receiver in phase, it would be equivalent (as our oscilloscope showed) to a single diagonal aerial, so we would be no better off. But the use of a two-part aerial is on the right lines, for we have only to introduce a 90° phase delay in the connection from one of the parts to give the receiving system a circularly polarized

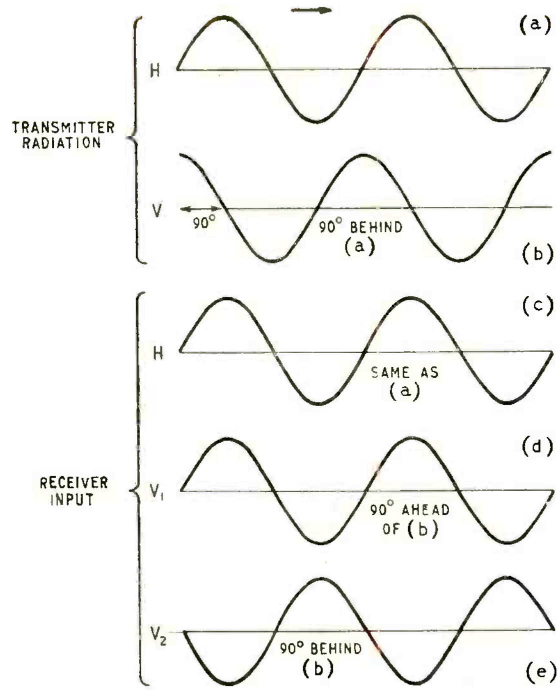


Fig. 6. (a) and (b) represent respectively the horizontal and vertical radiations of a circularly polarizing aerial system; (c) and (d) or (e) represent what is received by a similar aerial system after the signal picked up by the vertical portion is advanced or delayed relative to that from the horizontal portion.

characteristic. It is then equally responsive to waves linearly polarized at any angle; there are no blind angles.

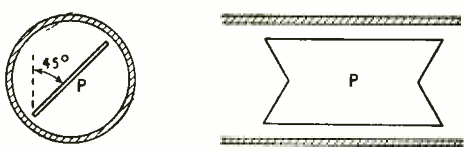
The oscilloscope experiments should have made clear how the 90° phase difference between the outputs of the two aerial elements should give these results, but there is no harm in thinking of it a little differently. The reason why the straightforwardly connected outputs of a horizontal and a vertical aerial combine to give diagonal polarization is that the outputs, being in phase, are always present together and combine just like forces or winds or velocities acting in different directions. But when one is 90° out of phase with the other, its maximum occurs when the other is zero and cannot affect it; similarly the other can have its undisturbed say at least twice per cycle. Now, whatever the angle of the incoming wave may be, it can't be totally without horizontal *and* vertical. So some of it is bound to be received.

Now that we have thoroughly convinced ourselves that a circularly polarized receiving aerial yields an output from waves linearly polarized at any angle, we may be unprepared for the news that there is one kind of polarization to which it is blind. But there is no contradiction; the exception is not *linear* polarization, but circular polarization of the opposite direction of rotation. To prevent the mental haze from rolling in again it may be advisable to stop a minute and think this one out.

In doing so, we must be careful what kind of diagram we use; if we were to try vector diagrams, in which differences in phase (involving *time*) are represented on paper by differences in angular *position*, the chances of getting muddled in this problem, which involves differences of both phase and angular position, would amount almost to a certainty. But I think there will be no danger if we regard the vertical and horizontal transmitting and receiving aerials as two independent channels of communication, in which (under ideal conditions) the vertical receiving aerial responds only to the vertical sending aerial, and similarly for the horizontal ones.

Fig. 6 (a) represents a brief sample of the radiation from the horizontal transmitting aerial. In order to cause circular polarization, the radiation from the vertical aerial must be 90° different in phase, so (b) shows what is going on there at the same time if the output is delayed 90°.

Supposing, for the sake of simplicity, that the receiving aerial is exactly a whole number of wavelengths distant, (c) shows what is being received by the horizontal part; it has the same phase as (a). That being so, what is received by the vertical part will have the same phase as (b). But because this is a circularly polarized receiving aerial system, it is provided with a 90° phase shift between its two parts. If the vertical part is advanced 90° relative to the horizontal (in practice this would be done by delaying the horizontal) the result is shown at (d), and this exactly reinforces what is being received on the horizontal part (c). But if the phase delay happened to be in the vertical part, the result would be as at (e), which would exactly cancel out (c) and give no reception.



(a) (b)

Fig. 7. (a) End view and (b) side view of section of circular waveguide containing dielectric plate P for converting vertical (or horizontal) linear polarization to circular, or vice versa. The ends of the plate are fish-tail shaped to avoid impedance mismatching which would cause part of the wave to be reflected.

I have gone into this in some detail, not so much to show how one can very ingeniously invent a receiving aerial that doesn't receive, but to lead up to another use for circularly polarized waves. One of the biggest problems in radar is to distinguish one thing from another, especially when they are both at the same place at the same time. For example, aircraft to be located may be in the midst of a heavy fall of rain which entirely blots them out on the receiving screen by sending back a permanent echo. Can the rain echo be eliminated without eliminating the aircraft echo?

One feature that distinguishes raindrops from aircraft is their shape. A spherical drop, being symmetrical around its centre, behaves equally to the horizontal and vertical components of a circularly polarized wave, so the wave reflected from it is also circularly polarized. But in the reversal of direction, the rotation of the polarization is also reversed; so if (as is usual) the aerial that sent out the original wave is also used for receiving the echo, it is blind to the echo. An irregularly shaped body such as an aircraft, however, (or even a flying saucer edge-on) is practically certain to reflect a little more at one angle than at another, the result being that the echo wave is elliptically polarized and does not entirely cancel out at the receiver.

This idea is not particularly new; it goes back to somewhere near the end of the war, and various trials then and since have shown a reduction in rain echoes of up to 26 dB, whereas the echoes from "targets" are only 4-8 dB weaker. Provided that the target echoes are strong enough to stand this weakening and still be visible, the result amounts to a practically complete victory over the rain.

There are other uses for circular polarization; for example, radar and other microwave aerials usually have to be capable of being turned around freely, and if it is not convenient for the whole station to turn with them this means that somewhere along the waveguide feeding the aerial there must be a rotating joint. If the waves carried by the guide were circular throughout, this would hardly be a problem. But there are reasons for preferring rectangular (linearly polarized) waves, and if nothing were done about it the transmission would vary from a maximum to zero as the aerial system turned through 90°. The solution to the problem is to convert the linear wave into a circular one when it comes to the joint, and then back into a linear wave directly afterward.

And how, you may ask, does one convert linear into circular polarization and vice versa? In the circular-polarization aerial systems we considered earlier we assumed that two linear polarizations (horizontal and vertical) were laid on, but here in the wave guide there is only one. And even when we have two, how is one of them delayed 90°?

As regards the first point, we have already noted that any one linearly polarized lot of waves is absolutely indistinguishable from two in-phase lots, polarized 90° apart. For instance, one lot polarized at 45° may be, for all anyone can tell, really two lots polarized at 0° and 90°. (A south-west wind can be regarded as a south wind and a west wind blowing at the same time.)

If one had the two linear polarizations in different feeders, the phase difference could easily be introduced by making one feeder quarter of a wavelength longer than the other. The only snag would be if one wanted to work over a band of wavelengths.

Where there is only one feeder, conveying what might be a single lot of linearly polarized waves, the trick is to insert in its path something that slows waves of one polarization more than another. A simple something of this kind is a thin sheet of dielectric such as polystyrene. Fig. 7(a) is an end view and (b) a side view of a piece of circular waveguide with such a plate (P) in position. Let us suppose that the wave going in is vertically polarized. Then it can be regarded as consisting of two equal components, one parallel to the plate and the other at right angles to it. The former is slowed and the latter not, so if the length of the plate is designed to cause the parallel component to fall quarter of a wavelength out of step, the outgoing wave is circularly polarized.

A second plate at right angles to the first delays the other component so that it comes into step again and the polarization is vertical once more. By setting it at any other angle, the polarization can be made linear at some other angle. In the rotating joint the plate, being fixed in the rotating part, automatically turns to the correct angle for setting the linear polarization in line with the remaining run of rectangular guide.

Electronic Digital Computers

1. *Basic Arithmetic Circuits*

By W. WOODS-HILL *

ALTHOUGH an electronic computer forms an impressively complex device when viewed as a whole†, the circuits used are in many cases simpler than those of a superhet receiver or a television time base. This simplicity is essential to the success of a computing machine in many applications. The machine may, for example, form an essential part of an industrial concern's wages and accounting organization, and for such work it must have much greater reliability than apparatus intended for entertainment. Generally it consists of five hundred or more valve circuits linked together into a working whole, and the failure of any one part can put the entire machine out of operation.

To achieve this reliability it is common practice for individual circuit " bricks " to be developed and used over and over again in their original form. Connection of the " bricks " to other circuits is done via isolating amplifiers and cathode followers to prevent any possibility of the circuits they are feeding from affecting their stability. Opportunistic juggling of special characteristics of the same circuit element when used in different parts of an apparatus, though quite legitimate in a television set or reflex superhet, has to be kept to a minimum in the computing machine. It distracts from the margin of safety of the circuit as originally designed and increases the variable factors to a point where servicing becomes difficult if not impossible.

Before coming on to the actual arithmetic circuits of the computer it is necessary to look at some of the " bricks " from which they are composed. The two main ones are (a) a bi-stable element, usually an Eccles-Jordan relay or trigger circuit and (b) a gate circuit. The Eccles-Jordan trigger is well known, but there are one or two points about it worth noting. In the circuit of Fig. 1 if V1 (a) is conducting then its anode voltage has fallen from 135 V to 45 V and the grid voltage has risen from −30 V to +2 V, measured at the circuit end of the grid stopper. Exactly the converse has happened to triode (b). The source impedance of the anode circuit is low but the grid impedance is high.

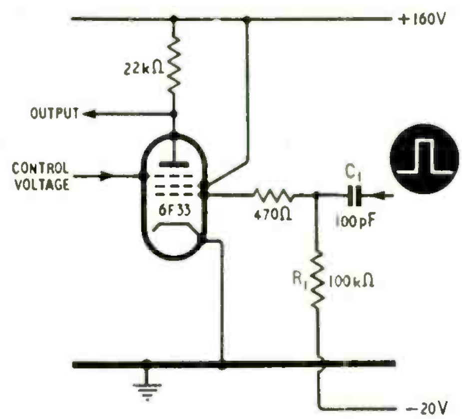
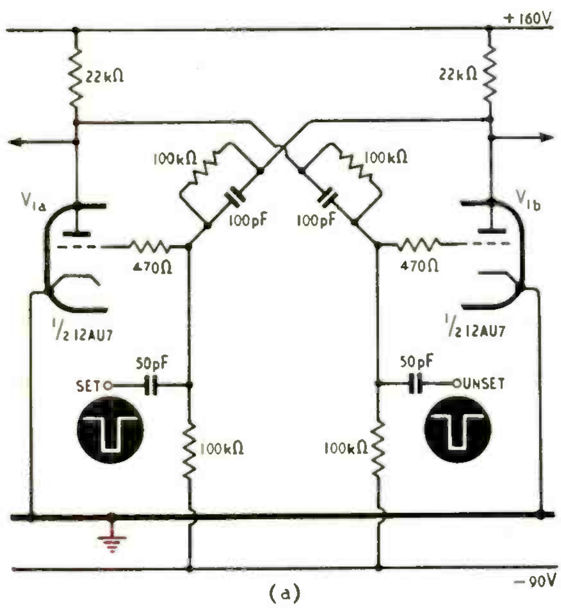


Fig. 2. Pentode gate circuit.

When triode V 1 (a) is conducting the circuit is said by convention to be " unset " or " off ". A negative pulse applied to the terminal marked SET will drive the V 1 (a) grid negative, effectively cutting it off, and the circuit will be unbalanced into the other state where V 1 (a) is cut off and V 1 (b) conducting. In this condition the circuit is said to be " set " or " on " and will maintain this condition indefinitely as long as the power is connected. Applying a negative pulse to the terminal marked UNSET will cut off V 1 (b) and restore the circuit to its original " off " state. The functional diagram for this trigger circuit is shown in Fig. 1 (b).

The gate circuit is not so well known and has many forms, but the simplest and easiest to design, though by no means the cheapest, is the pentode gate shown in Fig. 2. This is maintained cut off by connecting the grid through R_1 to −20 V. The suppressor " control voltage " is held at about earth potential. If positive pulses of 20 V or greater are applied to the grid through C_1, the valve will act as an amplifier inverter and the pulses will appear in the anode with a peak-to-peak amplitude of about

* British Tabulating Machine Company.
† For a broad introduction to the subject see " Computors " by " Cathode Ray," *Wireless World*, October, 1951.



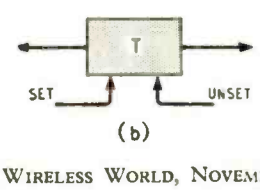


Fig. 1. (a) Eccles-Jordan trigger circuit, used for various purposes in digital computers, and (b) its functional diagram.

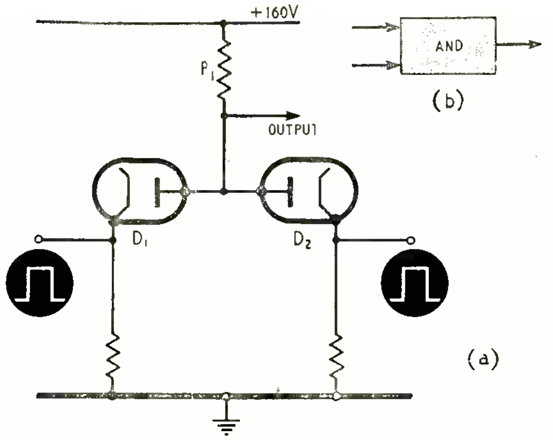


Fig. 3. Diode gate circuit (a) with functional diagram (b) of its use as a logical " AND " element.

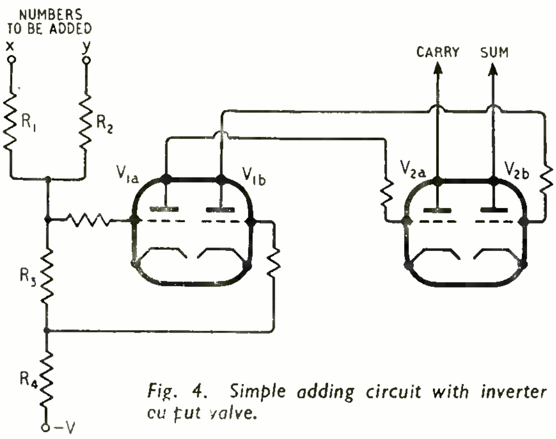


Fig. 4. Simple adding circuit with inverter output valve.

110 V. If the suppressor voltage is now brought down to −30 V the electron stream will be prevented from reaching the anode and the amplified grid waveform will no longer appear there. This is a very attractive way of controlling a pulse stream, because the circuit is extremely tolerant to varying parameters. For example, the grid waveform can vary any amount from 20 V amplitude upwards and the suppressor voltage anywhere from −30 V downwards, short of insulation breakdown, without interfering with the proper gating action.

If a gate circuit can be tolerated which requires the upper and lower limits of the voltage swings to be well defined then the diode circuit of Fig. 3 will cost considerably less. The output lead, though connected to h.t. via R_1, will not rise more than a few volts above earth because both diodes are conducting. If a positive square wave is applied to one diode, say D_1, this produces no change because the diode will cut off, as its cathode is driven more positive than its anode (negative anode volts). If, on the other hand, a positive pulse is applied simultaneously to both cathodes, then the output lead voltage will rise to the level of the highest square wave, because neither of the diodes will be conducting for the duration of the pulse. D_2 has effectively controlled the waveform from D_1. With germanium or selenium diodes the square waves are of 25 V–45 V amplitude and must be derived from a low impedance source such as a cathode follower or pulse transformer to minimize breakthrough via the finite (500 kΩ) back resistance or capacitance of the diodes.

The diode circuit in Fig. 3 illustrates another use of the gate—as a " logical " element which produces an output pulse only when two pulses are applied simultaneously to its inputs. In this sense it is known as an " AND " gate (because it needs a signal at one input *and* another signal at the other in order to operate) and the corresponding functional diagram is shown in Fig. 3 (b). Other versions with different methods of operation are " OR " and " NOT " gates.

In most computers the arithmetic is performed in binary notation. This is a " scale of two " notation, in which there can be only two possible symbols used as against the ten in conventional arithmetic. The carry, or point at which the same symbols are used over again, occurs after the tenth in decimals but after the second symbol in binary. The effect of this is such that one added to one $(1 + 1 = 2)$ causes a carry to occur because it is in effect adding half the radix value‡ to half the radix value. In decimals 5 is half the radix value, and $5 + 5$ is written $1 \leftarrow 0$, or more conventionally 10. In the case of binary notation 1 is half the radix, so that $1 + 1 = 1 \leftarrow 0$ or 10, which has a value of two decimal units.

It follows that binary two (or 10) plus binary two (10) will produce four as 100, four plus four will give eight as 1000, and so on, each binary place having double the value of the previous one. Thus we have:—

Decimal	0	1	2	4	8	16
Binary	00000	00001	00010	00100	01000	10000

Odd numbers are expressed as combinations of the above; for example, 5 in binary is produced by adding the symbol for four, 00100, to the symbol for one, 00001, and this gives 00101.

Because only two symbols are needed in binary notation they can be electrically represented in a computer as a voltage, say −100 V, being either present or absent at some point in a circuit, or by a switch being either closed or open, or by any other two-state device such as a trigger or a gate. The next thing to consider is how such electrical equivalents of binary notation can be manipulated by electronic circuits to perform arithmetic operations. To begin with take the simplest case—addition. Here, the circuit will have to obey the following rules of binary addition:—

Condition A	$0 + 0 =$	0
Condition B	$1 + 0 =$	1
Condition C	$0 + 1 =$	1
Condition D	$1 + 1 =$	$1 \leftarrow 0$ (or 10)

All that is necessary, then, is to devise a circuit that will give outputs corresponding to the right-hand column of answers when inputs corresponding to the two left-hand columns of numbers to be added are applied to it. We may not be able to follow the arithmetic operations of such a circuit in the same way as we can, for example, the operations of a decimal adding machine, but that is simply because our minds are more accustomed to decimal notation. As long as the circuit obeys the binary rules, however, we can be sure that it will produce the right answers, and that is all that really matters.

‡ The radix value is the number on which the system of numeration is based. In the decimal system it is 10, in the binary system 2.

There are a number of different types of adding circuits, but a simple one that will give the answers for conditions A, B and C and partly for D is shown in Fig. 4. If by convention a binary digit (that is, a 1) is represented by a fall in voltage of 100 V, say from + 150 V to + 50 V, then condition A (0 + 0 = 0) means that the voltage at both *x* and *y* is + 150 V and both halves of V1 are conducting, because both grids are going positive with respect to earth. This results in no output from the anodes of V2 (which is actually an inverter to counteract the phase reversal produced by V1). Condition B (1 + 0) means that the voltage at *x* is low while *y* is still high, so the junction of R_1 and R_2 falls approximately 50 V. This results in the grid of triode (b) going negative because it is connected low down the voltage-divider chain R_3R_4. The grid of triode (a) is still positive because it is connected higher up the chain. That is, (a) is conducting and (b) is cut off. After inversion by V2 this results in a fall of voltage (representing a 1) from the "sum" output (V2(b) conducting) but nothing from the "carry" output. Condition C produces the same result as B because the junction of R_1 and R_2 again falls 50 V as before.

Condition D (1 + 1) means low voltage on both *x* and *y*, which caused a fall of 100 V at the junction of R_1 and R_2. Section V1(b) is driven even farther negative with the same result as in conditions B and C, but V1(a) grid is now driven below cut-off for the first time and its anode voltage rises. The output after inversion now shows a digit (fall in voltage) on both lines, which is *not* correct. Only a "carry" digit should be present (1 + 1 = 1 ← 0) and V2(b) should not be conducting. A further valve must therefore be added to suppress the "sum" output for condition D. This takes the form of V3 in Fig. 5 which shows the complete adding circuit. The grid of V3 is fed from the anode of V1(a) which, as just described, is low under all conditions except the last, so that normally V3 is cut off and has no effect; but under condition D the anode of V1(a) rises, causing V3 to conduct, thereby shunting the anode of V1(b) and effectively suppressing the "sum" output.

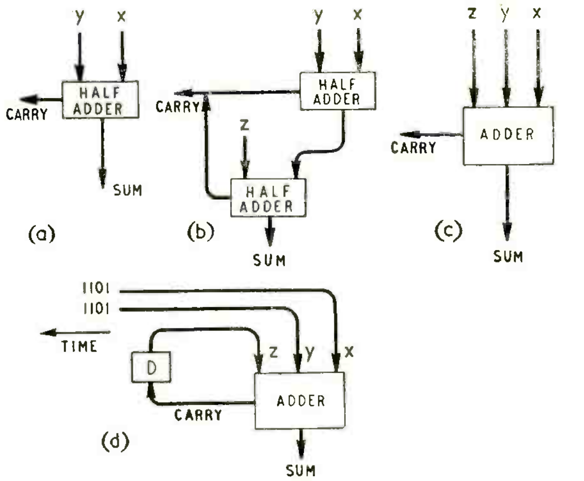


Fig. 6. Functional diagrams of (a) half adder, (b) complete adder with (c) its abbreviated form, and (d) an adder with a storage device for holding the "carry" output.

The type of circuit just described has become known in the computing world as a "half adder" and can be symbolized as in Fig. 6(a). The name springs from the fact that it will perform the addition of two binary numbers quite correctly but does not provide a means of accepting a "carry" produced by the addition of lower digits. For example, when one goes through the motions of adding 25 + 26 like this:—

$$\begin{array}{r} 25 \\ +26 \\ \hline 51 \end{array}$$

one says "six plus five equals eleven; one down, and carry one." Then, "two plus two, *plus one carried*, is 5." Not only has 2 + 2 been added to form a temporary answer of 4 but a second addition must be immediately performed to add the one and clear the "carry." Quite logically, then, a second identical circuit can be included in series with the first "half adder" to cope with the third input for the incoming "carry" digit. The symbolic circuit for an adder then becomes Fig. 4(b) with *z* as the third input, and this in turn can be abbreviated to Fig. 6(c).

The explanation will not be clear until it is realized that this adder will deal with, say, two 10-digit binary numbers presented simultaneously to the two inputs *x* and *y* in pairs in serial form, starting with the lowest value digit. For example, 13 + 13 would look like

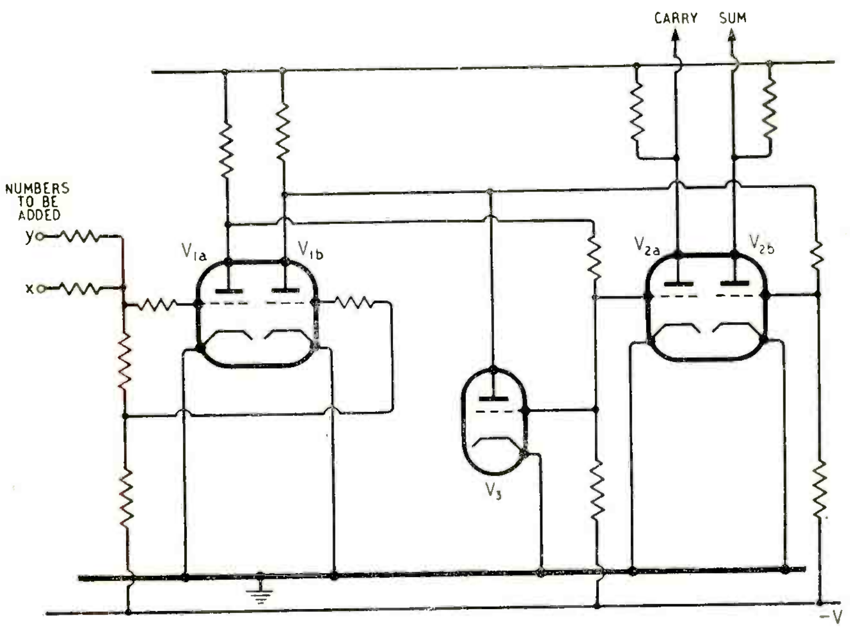
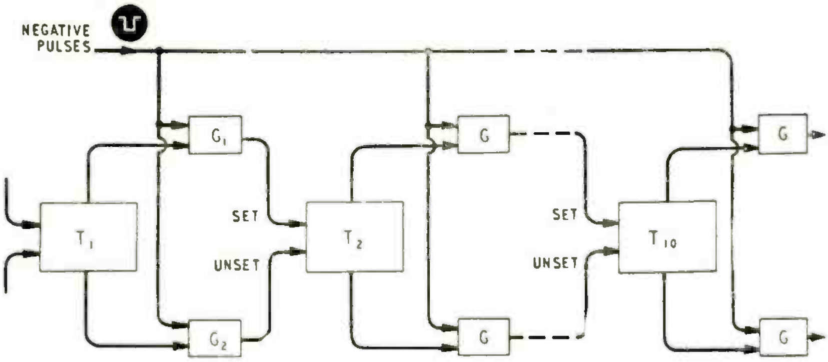
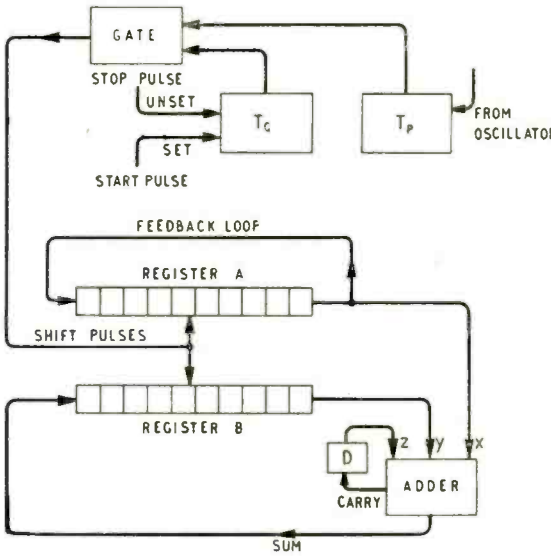


Fig. 5. Complete "half-adder" circuit developed from Fig. 4.



Left: Fig. 7. Shifting register for temporary storage of numbers necessary in adding.

Below: Fig. 8. Block diagram of system for adding numbers held in two shifting registers.



1101 + 1101 and would be presented to the x and y inputs in the form shown in Fig. 6 (d). As each pair of digits is presented the addition may or may not form a "carry," but if one is formed it must be stored until the next higher value digit pair is presented and then added to the sum of this next pair via input z. The storage, represented by the device D in Fig. 6(d), need consist of nothing more complicated than a lumped-inductance delay line with a delay time equal to one digit period, or a trigger circuit (similar to Fig. 1) which would be "set" by the carry pulse.

In most digital computers the numbers to be added are held in a storage system, say a magnetic drum, and they emerge in some kind of sequence as the drum rotates. In the ordinary way, then, the two numbers in Fig. 6(d) would not arrive simultaneously at the adding circuit. To achieve this type of presentation it is necessary to use an additional temporary store which will hold the first number until the second one arrives and then feed them both, a pair of digits at a time, into the adder. Such a storage system is usually known as a "shifting register."

If, as depicted in Fig. 7, ten trigger circuits are set up in a row they will store (by their states of operation) any discrete pattern representing a binary number of not more than ten digits. To get a number to shift along this row requires the addition of two gates between each trigger and a source of negative pulses. Trigger 1 controls two gates G_1 and G_2 such that G_1 is open and G_2 closed when T_1 is "set" and the reverse if T_1 is "unset." The gates are connected to the next trigger T_2 so that a pulse from G_1 will "set" T_2 while a pulse through G_2 will "unset" it.

Because T_1 governs which gate is open, then on the application of a negative pulse to both gates only one gets through and causes T_2 to assume whatever state T_1 was in at the instant of applying the pulse. Similarly T_2 influences T_3, T_4, and so on up to T_{10}. Thus the application of one negative pulse to all the gates will cause whatever pattern was in the register to shift one stage along. Applying ten pulses will shift the pattern right off the end unless the end pair of gates is connected back to the first stage, in which case the pattern will have recirculated back to its starting position.

It is now possible to assemble in one block diagram (Fig. 8) all components needed to perform the addition of two binary numbers. The sequence of events is as follows. Trigger T_P is continuously triggered by pulses derived from an oscillator. The resulting pulses from T_P are applied to a gate. A "start" pulse "sets" T_G which opens the gate. The output of the gate causes both registers to shift their contents into the adder. The adder then sums each pair of digits and takes care of the "carrys" as it goes, returning the sum to register B. Notice that register B loses its initial contents (if any) which are replaced by the sum, but on the other hand register A has a feedback loop so that not only does it present its digits to the adder but preserves them for future use. At the end of ten pulses T_G receives a "stop" pulse, becomes "unset", closes the gate, and stops the action just as the digits in register A have returned to their initial positions and the sum is complete in register B.

The same equipment can be used to do multiplication. To multiply, for example, $3 \times 4 = 12$ the binary equivalent of 3 is inserted in register A, zero into register B, and the circuit is made to perform four addition cycles. The 3 will then be added four times to the contents of register B (initially zero), which gives:

$$0 + 3 + 3 + 3 + 3 = 12$$

How the machine causes the value of the multiplier factor to control the addition cycles will be explained later.

Before continuing it may be of interest to look at the practical circuitry of the part of Fig. 8 comprising triggers T_G and T_P and the gate. In Fig. 9, trigger T_G (V1) is providing a controlling voltage from its grid circuit via a cathode follower, V2, to the suppressor of gate V3. The grid of V3 is supplied with a train of square waves derived from trigger T_P (V4). It is assumed that V4 is being triggered by some externally generated stream of pulses at, say, 30 kc/s. As the grid swing of a trigger is − 30 V to + 2 V then if V1 is "set" the pentode gate V3 is open (suppressor at + 2 V) and the amplified inverted pulses will appear in the pentode anode circuit; but if V1 is "unset" then the gate is closed because its suppressor is at − 30 V. Notice that there is no isolating cathode follower between trigger V4 and gate V3 because the grid is the first element in the pentode electron stream and contains very little modulation which might accidently upset trigger V4.

To return to arithmetic operations, subtraction can be achieved, apart from building a subtractor, by using the adder to add numbers in complement. A complement is the difference between a number and its radix value. In decimals they are:—

Number	1	2	3	4	5	6	7	8	9	10
Complement	9	8	7	6	5	4	3	2	1	0

which is ten variations and would be quite difficult to produce automatically; but binary comes to the rescue once again because there can only be two:—

Number	1	0
Complement	0	1

which in practice simply means inverting the voltage swings with a valve so that a falling voltage becomes a rising voltage.

Why *adding* a complement is tantamount to *subtracting* a true, will be easier to understand in decimals. Take for example the subtraction 6 − 3. The complement of 3 is 7, so if we add 7 to 6 we get 6 + 7 = 1 ← 3. Ignoring the "carry" the answer is correctly 3.

It will now become clear how the cycles of multiplication mentioned above can be controlled by a number. If our example 3 × 4 is taken, then the figure 4 is placed in complement (6) into some counter whose capacity is exactly 10. At the end of each cycle of addition the counter is arranged to advance one step, so that at the end of the 4th cycle the counter will

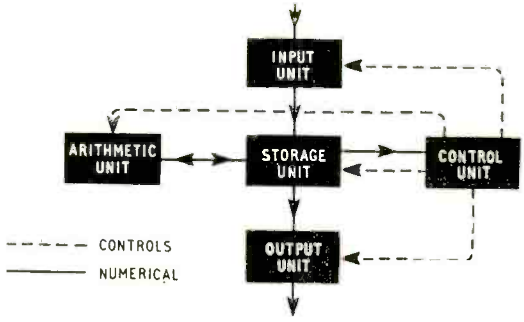


Fig. 10. Simplified block diagram of complete computer.

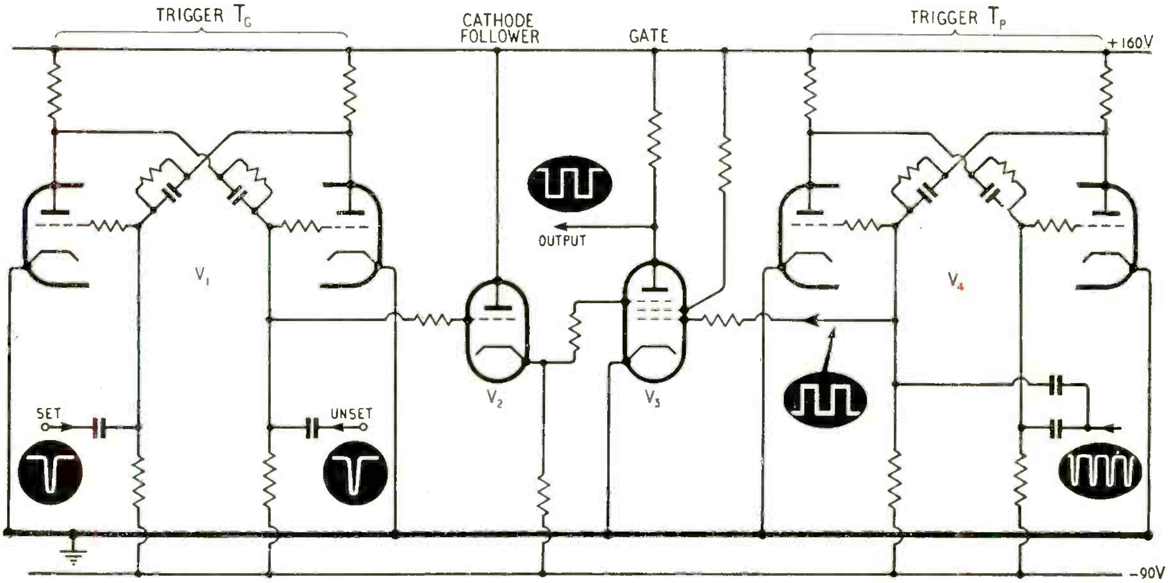
"spill over" (because 6 + 4 = 10) and this "spill over" can be used as a "stop pulse" in Fig. 8.

Division is very much the reverse of multiplication in that one factor is repeatedly subtracted from the other, and a tally of the number of times a subtraction is successfully achieved is accumulated in a counter. For example 8 ÷ 2 is performed as 8 − 2 − 2 − 2 − 2, the answer being 4 subtractions of two. The action is stopped as soon as 8 is reduced to zero or, in the case of an imperfect divisor, becomes a negative value.

To describe all the other circuits of a digital computer would be outside the scope of this article, but it may be helpful to glance at the general organization of a typical machine. The block diagram Fig. 10 gives some idea of this. The whole of Fig. 8 and some other circuits for doing arithmetic operations have been condensed into the block marked "arithmetic unit." The other blocks contain equipment built from similar "bricks" but connected to perform different functions.

First of all the "control unit." The job of this unit is to feed out to the whole of the rest of the machine trains of pulses and start/stop pulses as they may be required, also d.c. voltages to gates for routing numbers from one unit to another. It will activate these controls when instructed to do so by means of "program" numbers (instructions) delivered to it from a "program" section of the storage unit.

Fig. 9. Circuit of system for producing a predetermined number of shift pulses in Fig. 8.



This storage unit consists of two sections, usually of a magnetic drum, capable of storing 2,000 or more groups of binary digits, each group (known as a "word") containing approximately 32 binary digits. One section stores the numbers upon which arithmetic is to be performed while the other is the "program" section devoted to storing instruction numbers. The storage system as a whole will be capable of sending numbers to the control unit, sending to and receiving from the arithmetic unit, and sending to and receiving from the input and output units.

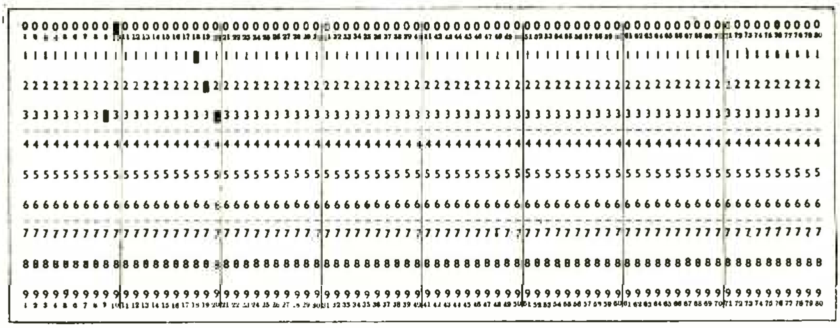


Fig. 11. Typical punched-card for feeding numbers into a computer.

These input and output units can take many forms, from magnetic tape to typewriters, and they contain electronic circuitry for coding decimal numbers to binary notation and decoding back again. Punched-card reading and printing equipment is used a great deal, and a typical card for use with this is shown in Fig. 11. From the top to the bottom of the card there are ten possible places to punch a hole, 0 to 9, so that a hole punched three positions down will have a value 3. The column or position from the right-hand edge of the card will signify its decimal value, i.e., 3 punched in the second column will have a value of 30. As very few numbers require more than ten columns, lines are drawn down the card to segregate each number, the sections between lines being known as fields. Fig. 11 shows 30 punched in the first field and 123 in the second. These cards, when passed by means of rollers through the machine (usually at about 100 per minute), allow contacts to drop on to a sensing roller wherever a hole is punched. The impulses from these contacts are then fed via a coding device to the storage unit. The punched-card output unit consists of a printing machine in which 80 letters in a complete line of type can be printed simultaneously. This gives a rate of typing equivalent to 1,000 words a minute. Outgoing information from the storage unit feeds via a decoder to electromagnets controlling the setting of the type bars.

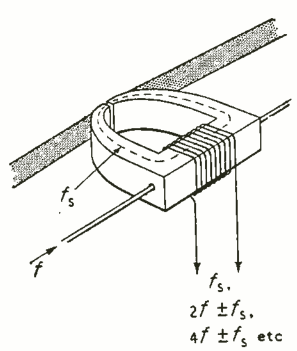
Finally, it is as well to recall that this article is an introduction to computer circuits in general and is not intended to represent any particular machine. Though it is quite feasible to build a computer with as few as 5 different types of circuit, most machines have 20 or more. The S.E.A.C. machine in the U.S.A. on the other hand is said to use only 3 types in its "logical" circuits.

VERY LOW FREQUENCIES FROM TAPE

IN the conventional magnetic tape reproducer the output voltage from the head is proportional to the rate of change of flux induced by the tape. Consequently, for a constant peak induction the output falls with frequency at 6 dB per octave and at very low frequencies the output may be little more than the hum and noise level of the amplifier. This is not likely to occur at audio frequencies but would preclude the use of magnetic tape for data recording which involves infra-sonic frequencies.

A special type of head has been evolved by E. D. Daniel (B.B.C.) for this type of work and is described in the *Proceedings of the Institution of Electrical Engineers*, Part B, No. 4, Vol. 102 (July 1955). The object of the design is to derive an output which is proportional to the magnitude and not to the rate of change of flux; the system can, in fact, be used to explore a transient slowly and in detail.

The basic principle is to cause the signal flux to modulate a high-frequency flux (which does not, in fact, reach the gap) and to pick up the resultant product by means of a search coil. There are points of similarity with a second-harmonic magnetic modulator and with a sensitive magnetometer described by T. M. Palmer (*Proc. I.E.E.*, Part II, October 1953).



Simplified diagram of flux-sensitive, low-frequency magnetic reproducing head.

In the accompanying simplified diagram it will be seen that the back leg of the magnetic core of the head encloses a single straight conductor, arranged symmetrically along the axis of a coil wound over the outside of the core. The latter is conveniently built up from pieces of one of the ferrite materials with grooves ground to fit on each side of the wire. A current of the order of amperes at a high frequency f in this wire generates a cylindrical flux inside the core, but as the linkage with the coil is small there is no significant output until a polarizing flux f_s due to the signal is applied in a direction at right angles to the high-frequency flux. The magnetic characteristics of the core material, which is being worked near saturation, will also no longer be symmetrical, and even-order harmonics, of which the second is the most important, will appear in the coil. After passing through a band-pass filter to select the second-term products, the output is fed to a balanced phase-sensitive detector in which the "carrier" frequency is balanced out by a variable-phase auxiliary oscillator ($2f$).

The head is sensitive to stray fields and must be well shielded. Any residual flux can be balanced by a d.c. current (of the order of microamperes) through the coil.

To take full advantage of the system the length of contact between tape and head should be at least half a wavelength of the lowest recorded frequency, but even with standard core shapes the published response shows no falling off below 1 c/s at a tape speed of 1 in/sec.

It is suggested that the system will find its chief application where low frequencies and long playing time are required as in cardiography or encephalography, when it may be necessary to keep observation of long periods for possible abnormalities.

Component Tolerances

By H. S. JEWITT, B.Sc.(Eng.)*

A Reminder of Their Effects on Circuit Performance

IT is often thought that the function of the circuit design engineer is to produce a circuit that will meet a given specification. This is, of course, quite correct, but one aspect of his job which tends to be overlooked is that he must also be what, for want of a better term, may be called a tolerance engineer. To produce in the laboratory a circuit to perform some operation may or may not be difficult according to the complexity of the required operation, but this is not enough: it is vital to ensure that the circuit can be reproduced in even small quantity production with an acceptable performance, as otherwise the design side of the work has been wasted. To this end, the effect of variation of the circuit components on the circuit performance must be examined, bearing in mind the fact that component manufacturers must, of necessity, be allowed some latitude in the values of their production components.

This examination must be practical in its approach. It is possible to specify highly accurate components in many places in a circuit and thereby produce a level of performance which may be unnecessarily high and will certainly be very costly. As an instance of this, the resistor may be considered. The ordinary composition resistor is a cheap component and is commonly available in tolerance ranges of ±5%, ±10%, and ±20%, the price varying, of course, with the tolerance demanded. The wire-wound resistor and the high-stability carbon type are both available with better tolerances, ±2% or ±1% or even better: but these components are much more expensive than the composition resistor, and replacement of a large proportion of the composition resistors in an equipment by the high-accuracy types might well double or treble the cost of the equipment. It may be that the level of performance demanded is such that this has to be accepted, but this is a rare case, and it should be the aim of the tolerance examination to make certain, not only that the circuit performs satisfactorily when component tolerances are taken into account, but also that high-accuracy components are called for only when it is strictly necessary that they should be used. A very practical point about the use of such components which probably lies within the experience of most design engineers of today is that delivery dates tend to be months later than those for the lower-grade components.

Another aspect of tolerance engineering is to determine what the circuit performance will be with specified components. It is well known that, for example, a wire-wound resistor is not a practical resistor for use in an i.f. amplifier at, say, 60Mc/s centre frequency, and neither, generally, is a spiral-track high-stability resistor. Thus, the designer of such a circuit must accept the fact that he has no option but to use composition resistors, and decide (a) whether his chosen circuit will give the desired performance with the tolerances of these components or (b) whether some other configuration would give a better performance with these tolerances.

It should be, but unfortunately is not always, realized that to find a resistor colour-coded 1000 ohms whose value is exactly 1000 ohms is a rarity, and that, for a ±10% tolerance, the value may lie anywhere between 900 and 1100 ohms. Nor is it correct to assume that the majority of a given batch of components will have values centred closely around the nominal value, particularly for the larger tolerances: they tend, rather, to have values which lie in two bands towards the two edges of the permissible range of values for the given tolerance. The circuit component which is an exception to this is the valve; a given batch of valves tends to have parameters centred closely about some value in the permissible range of those parameters, the value usually differing for different batches of valves. Thus, it is most important to know what the expected performance variation with component tolerance will be.

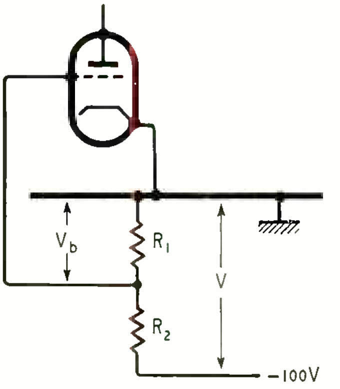


Fig. 1. Typical biasing circuit to illustrate the effects of component tolerances.

Practical Example

A simple example of this might be a biasing chain as shown in Fig. 1. In this circuit, R_1 and R_2 form a potentiometer network across the 100-volt negative supply to provide the correct bias voltage for the valve grid. Let it be assumed that the valve anode current is to be cut off; in some possible circuits a very small flow of anode current could cause the valve power dissipation rating to be exceeded so that this requirement is not a fictitious one. If the valve data is consulted, it may be found that the nominal cut-off voltage is −10 volts. Then R_1 and R_2 may be chosen to produce a little more than this minimum value: the values chosen might well be R_1 = 5.6 kΩ, R_2 = 47 kΩ, and the resultant bias is then −10.6 volts. But if these resistors are selected to a 20% tolerance, and R_1 is at its minimum value (= 4.48 kΩ) and R_2 at its maximum value (= 56.4 kΩ), then the bias might fall to 7.35 volts. It is very clear that the choice made, of a 20% tolerance, will lead to un-

* Decca Radar.

satisfactory performance in a large number of the sets built using this circuit. Reduction of the tolerance limit to 5% effects an improvement, and gives a possible minimum bias level of −9.73 volts. If the nominal bias level, that is, the level with both resistors at their nominal value, be now raised from 10.6 volts to a value of about 11 volts, the valve will always be cut off.

So far, attention has been focused on the potentiometer network, and it has been seen that the effect of resistor tolerance can be satisfactorily overcome. Now the valve itself must be considered. The manufacturer states that the cut-off bias is −10 volts for a nominal valve, and, in fact, if he is consulted, he will state that the possible spread of cut-off voltage for the valve type is from −7 to −13 volts (taking typical figures). In the light of this information, the whole problem has to be reconsidered, with a new minimum bias level of −13 volts as the target, requiring a nominal level of perhaps −14.5 volts. The alternative is, of course, to recognize that an equipment in which all parameters simultaneously assume their worst possible values will be rare, and that this equipment may be rejected: but this can be a dangerous practice, for it leads to a relaxation of standards and possibly to future servicing difficulties with the equipment. Whichever philosophy is adopted, these tolerance calculations must be done at a very early design stage if they are going to be done at all. This may be explained by slightly extending the example above. Let it be assumed that the valve is to be triggered by a positive trigger pulse which must drive the grid to zero grid voltage for satisfactory triggering. Then the original bias level requires a trigger pulse of 10 volts, and the final bias level one of 14.5 volts amplitude. Such a change in triggering pulse level is considerable: if the complete equipment had been designed and built without a consideration of tolerance effects, and it had been found, by experience, that this change was necessary to obtain a satisfactory performance, a complete redesign might well be needed to produce it.

Mathematical Approach

The example of tolerance effects considered above has been a simple one. It should be noted now that the use of the mathematical differential of the circuit equation will eliminate much laborious arithmetic, provided that it is realized that the differential approach only gives exact answers for infinitesimally small changes: but it is sufficiently accurate for this purpose over normal electronic engineering tolerances. Thus the bias voltage V_b of Fig. 1 may be expressed as

$$V_b = \frac{R_1}{R_1+R_2}.V$$

This expression may be differentiated with respect to R_1, assuming R_2 to be constant, and then with respect to R_2, R_1 assumed constant, to produce two equations relating the change of V_b to the changes of R_1 and R_2. These equations are

$$\frac{dV_b}{dR_1} = \frac{R_2}{(R_1+R_2)^2}.V \qquad (R_2 = \text{constant})$$

$$\frac{dV_b}{dR_2} = -\frac{R_1}{(R_1+R_2)^2}.V \qquad (R_1 = \text{constant})$$

Then the change of V_b for a change dR_1 in R_1 is given by

$$dV_{b(R1)} = \frac{R_2}{(R_1+R_2)^2}.V\ dR_1$$

and similarly for $dV_{b(R2)}$, and, since interest here lies in the minimum value of V_b, this can be stated as

$$V_{b(min)} = V_b - dV_{b(R1)} + dV_{b(R2)}$$

The positive sign for $dV_{b(R2)}$ is necessary since the sign of the differential is negative, indicating that V_b decreases as R_2 increases.

This simple example indicates both the need for, and the solution to, tolerance engineering of electronic circuitry, and, in general, this may be done, circuit by circuit, for the whole of an equipment. The process tends to become laborious for a large equipment, but it is hoped that the necessity for it has been adequately established. In more complex circuits, the same method may be used to great effect; the circuit equation is generally known from the design process, and differentiation of it is not generally difficult, whereas the arithmetic involved in considering the variation as applying to each component in turn with numerical values is often staggering. It is not proposed to give an example of this, as every case is a special one in this work, and no useful purpose could therefore be served.

Preset Adjustments?

From what has been said so far, it will be clear that one method of solving the problem of performance variation with component tolerance is the use of preset adjustments. Thus, in the example above, a suitable portion of R_1 and R_2 could be inserted in the form of a variable potentiometer, which could be set on each individual unit to give a suitable cut-off bias for the valve. This seems, at first glance, to eliminate the whole need for tolerance engineering, but this is a false conclusion. The preset itself has tolerances, and its value must be so calculated that its range of adjustment covers the tolerance variation of R_1, R_2, the cut-off bias voltage, and itself, so that tolerance examination is still necessary. The whole of R_1 and R_2 could be made a potentiometer to avoid tolerance calculations (the brute force attack) but this must give only a rough control over V_b, and may also need a large component to dissipate the power involved.

The biggest objection to this solution to the problem is that, remembering the number of circuits involved in almost any piece of equipment, the numbers of preset controls needed would be fantastic. It is probable that some presets must be used, and indeed should be used to provide a good level of performance, but the number of these must be cut to the bare minimum, on both cost and convenience grounds. The cost angle needs little elaboration—a variable resistor is more expensive than a fixed one. Convenience is a factor affecting the ultimate user of the equipment. Adjustment of presets is necessarily a job for a skilled man, who is neither always available nor cheap to employ, so that his attentions should be needed as little as possible. The user himself rapidly gets a poor opinion of a set needing frequent skilled attention. Last, but not by any means least, it is surprising how many people, whether skilled or unskilled, cannot resist the temptation, if they see a knob or other means of adjustment, to twiddle it

So, presets must be reduced to the minimum and preferably be hidden away, with screwdriver slots rather than knobs and possibly locking devices in addition. In the process of hiding them away, however, it is as well not to forget that they do need adjustment, and to arrange things so that the preset and the indicator by means of which it is being set can be effectively used by people of normal proportions, with their eyes in the normal places. Few things are quite so irritating to the maintenance engineer as finding that the only person able to adjust a given preset is a dwarf with four-jointed 8-ft arms and eyes on flexible stalks.

It is usually possible to select the value and position in the circuit of a preset control so that it compensates for the effect of a number of component tolerances. Before presets are positioned in the circuit, therefore, their effects should be carefully considered to see whether their number can be reduced by altering their placing in the circuit.

It is hoped that this article will underline the need for tolerance engineering at a very early stage in the design process. The importance of this, and of its solution in terms of adequate performance and reduced cost, cannot be over-estimated in an industry in which ever-increasing circuit complexity poses new problems of economic manufacture and satisfactory use of equipment.

Modified A.F. Millivoltmeter

Reduced Switching Transients and a More Linear Scale

By R. SELBY*

THIS instrument is based on the design for an audio-frequency valve voltmeter by S. Kelly†, and incorporates additional features to meet specific requirements.

An instrument was first built to the published design, incorporating a meter having a full-scale deflection of 1 mA, with a copper-oxide bridge rectifier and a suitable series resistor. This performed quite well, but it soon became apparent that operation of the range switch was accompanied by switching transients in the meter.

Consideration showed this to be due to the fact that the range selection potential divider acts as such, not only to a.c., but also to the standing cathode current of the first valve. When changing, for example, from the ×1 to the ×0.1 positions, there is a change of about 30 volts in the d.c. potential at the moving arm of the switch, and, owing to the good l.f. response of the amplifier, this appears as a surge at the output.

In the modified design the cathode resistor is separated from the potential divider, feeding the latter through a large capacitor which blocks the d.c. but offers low impedance to a.f. No alterations to the values of the resistors are necessary. The cathode resistor may be of the order of 50 kΩ, and a high-stability type is unnecessary. The effective impedance of the cathode-follower load is approximately halved by this arrangement, thereby reducing the maximum signal which can be handled without distortion, but this will not usually be a material factor.

Some difficulty was experienced with the original design in securing a linear scale. This is, of course, a normal feature of rectifier-type voltmeters, due to the characteristics of metal rectifiers. The meter which it was desired to employ had a resistance of 50 ohms and a full-scale deflection of 1 mA. A curve was plotted (Fig. 1) showing the relationship between scale reading and applied voltage when used with an instrument-type bridge rectifier and a series resistor of 3,800 ohms. A further curve was taken with the same meter and a pair of germanium diodes in a half-bridge circuit as shown in Fig. 2. This curve (not reproduced) showed a higher degree of linearity owing largely to the higher current being drawn with this circuit.

A linear scale is obtained in commercial multi-

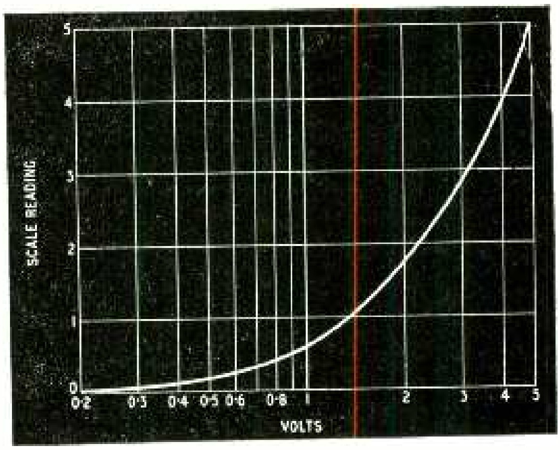


Fig. 1. Calibration using a 0 to 1-mA meter in a bridge rectifier with a 3800-ohm series resistance.

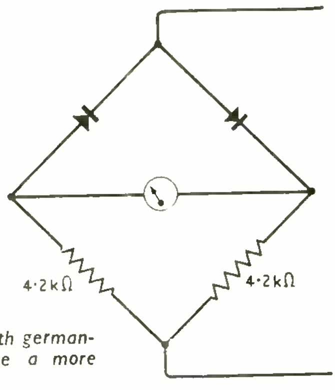


Fig. 2. Meter circuit with germanium diodes which gave a more linear calibration.

* Metropolitan Relays Ltd.
† *Wireless World*, June 1951.

purpose test meters, but only at the expense of lower resistance and higher consumption than on the corresponding d.c. range. For example, the latest model of a very widely used instrument consumes 10 mA at f.s.d. on the 10-V a.c. range and 40 mA on the 2.5-V range, whilst another model consumes 5 mA at 10 volts. The use of such meters externally as the indicating device in the original valve voltmeter circuit imposes certain restrictions on accuracy. At low frequencies the reactance of the coupling condenser becomes appreciable in relation to the meter resistance, whilst the impedance of the load presented to the cathode follower is so low as to reduce seriously the undistorted output.

One method of overcoming this difficulty is to employ a low-consumption meter with a specially calibrated non-linear scale. This course did not appeal to the writer who is more at home with a soldering iron than a draughtsman's pen. In the original version it was possible to overcome the difficulty to a reasonable extent by feeding the meter through a fairly high series resistor, so that variations in rectifier resistance represent only a small fraction of the total resistance in circuit. Clearly, sensitivity is lost. In many designs, the meter is fed from a pentode or high-impedance triode in order to improve linearity.

In the modified design, the cathode-follower output has been retained, but the meter has been placed in the negative feedback circuit, thereby substantially linearizing the scale shape. It was found that with this system there was no visible difference in linearity between the copper-oxide full bridge and the germanium half bridge types of rectifiers.

A further difficulty arose when attempts were made to modify the ranges. For the writer's purpose, the desired scales ranged from 0–50 mV to 0–5 V only, and it was hoped that this reduction in sensitivity, together with improved long-term stability, could be achieved by increasing the percentage of negative feedback. Unfortunately this was found to cause serious instability, the meter swinging violently at a periodicity of 2 or 3 c/s.

The circuit was therefore finally modified to that

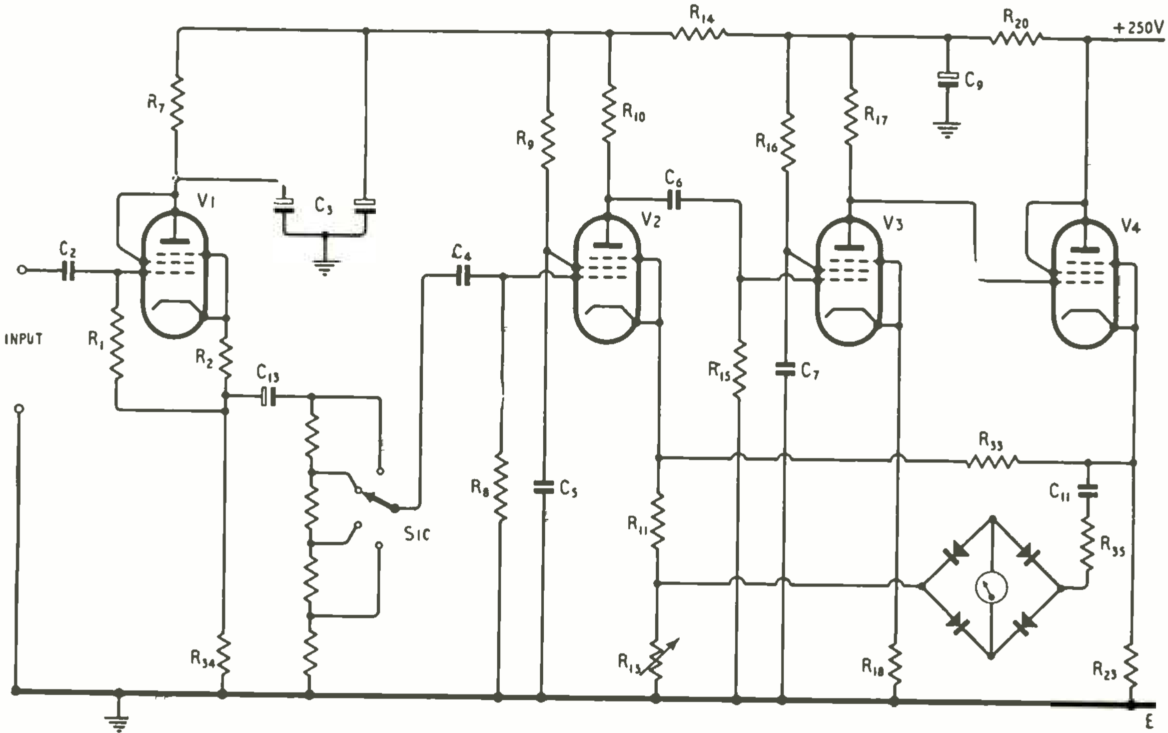


Fig. 3. Modified circuit in its final form. Components are numbered to conform with the original circuit (June 1951).

List of Components

R_1 2.2MΩ	R_{16} 390kΩ	C_3 16 + 16μF
R_2 3.3kΩ	R_{17} 100kΩ	C_4 0.5μF
R_7 50kΩ Wire-wound	R_{18} 680Ω	C_5 0.5μF
R_8 470kΩ	R_{20} 10kΩ Wire-wound	C_6 0.5μF
R_9 570kΩ	R_{23} 10kΩ Wire-wound	C_7 2μF
R_{10} 100kΩ	R_{33} 890kΩ High-stability	C_9 16μF
R_{11} 470Ω Wire-wound	R_{34} 47kΩ	C_{11} 8μF Metallized paper (or "Superlytic")
R_{13} 50Ω Variable	R_{35} 3.8kΩ High-stability	C_{13} 8μF (T.C.C. "Superlytic")
R_{14} 20kΩ		V1, V2, V3 6AM6 or EF91
R_{15} 100kΩ	C_2 0.01μF	

shown in Fig. 3, from which it will be seen that the amplifier (V3) is now direct-coupled to the cathode-follower output stage, whilst a direct-coupled feed-back path is now provided through R_{33} from the output valve cathode to the cathode of V2. Two sources of phase variations are thus removed and a very high feedback factor may be used without trouble, if required.

A second feedback path is provided by returning the meter also to the cathode circuit of V2. Apart from the normal overall improvement to the amplifier, this has two beneficial effects. The reactance of the coupling condenser C_{11} no longer introduces error at low frequencies and the meter scale becomes substantially linear, because variation in rectifier resistance introduces a compensatory variation in the gain of the amplifier. It was found, however, that there is a limit to the amount of feedback which can be used in this path without instability. This again showed itself as a surging or oscillation at very low frequency. The procedure in choosing component values is, therefore, to apply the maximum feedback in the meter circuit compatible with stability, after which selection of R_{33} may be made in accordance with the overall sensitivity desired. This will be determined by the ranges required and the particular meter used. The resistor values quoted relate to the meter and ranges referred to earlier. It should be noted that although the lowest range has been raised to 0–50 mV, this does not imply that the highest may be 0–50 V, since such a signal would overdrive the input cathode follower.

A few other small modifications should perhaps be explained. The cathode bias resistors of V2 and V3 have higher values than the 100 ohms shown in the original circuit. Using 6AM6 or EF91 type valves, 100 ohms gives only about 0.3 V bias. Further, the use of higher values, unbypassed, introduces some secondary feedback within the main loop, thereby improving stability. The screen feed resistor of V3 has been reduced from 470kΩ to 390kΩ in order to lower the anode potential of V3 and therefore the grid potential on V4. The suppressors of V1 and V4 have been strapped to the cathodes rather than the anodes, to conform with the valve makers' recommendations. The use of 0.5μF condensers for coupling and decoupling in place of 0.25μF has no significance—a quantity of 0.5μF condensers were available.

The grid resistor of V2 is returned to earth instead of to the lower end of R_{11} as in the original circuit, since it was found that this was one cause of the meter surging during range switching. This is due to the removal of feedback during the momentary break in the circuit when the switch arm is moving from one contact to the next. Hum and signal leakage (by stray capacitance) are temporarily amplified with the full gain of the amplifying stages. This can be seen more easily by re-drawing the essentials of this part of the circuit as in Fig. 4. This trouble would not arise with a switch which shorted adjacent contacts during rotation. It is desirable to screen C_4 and its associated wiring to reduce signal leakage by stray capacitance, when a non-shorting type of switch is used.

The condenser C_{13} coupling the cathode of V1 to the potential divider should be of large capacitance but small physically. A T.C.C. "Superlytic" 8μF, 150-V working type was used, and it was found possible to dispense with C_4, provided one remem-

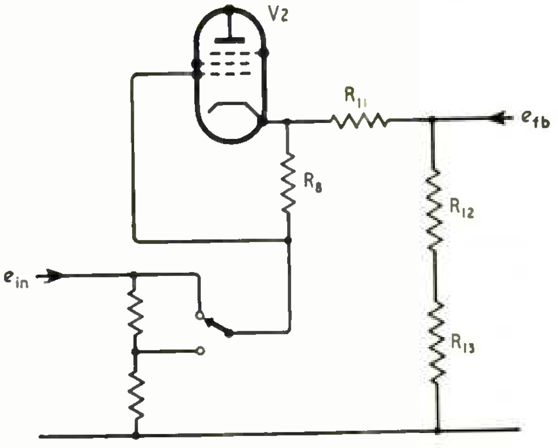


Fig. 4. Simplified detail of grid-cathode circuit of V2 to show possibility of hum and signal leakage amplification when the range switch breaks contact between adjacent positions.

bered to leave the range switch on its least sensitive position for a minute or so after first switching on from cold, in order to allow polarization to become complete. This type of capacitor has an insulation resistance, after polarization, approaching that of paper types. However, as at the time of writing it is not yet widely available, a normal electrolytic may have to be used in many cases, when C_4 must be retained to isolate the grid of V2 from d.c. leakage. The calibration checking arrangements given in the original description may be retained, but have been omitted from the diagram for simplicity, as has the power supply section.

One desirable feature not incorporated would be automatic protection against accidental meter overload. This might possibly be achieved to some extent by reducing the resistance of R_{23} to a figure which would cause the output to flatten off slightly above that required for full-scale deflection of the meter.

Television Interference

DURING some experimental work on a two-band television tuner it was found that some interference with Channel 1 was being experienced from Channel 9. The set had the new standard intermediate frequencies of 34.65 Mc/s vision and 38.15 Mc/s sound.

For Channel 1 the oscillator was at $45+34.65=79.65$ Mc/s. Its second harmonic was thus 159.3 Mc/s. The difference frequency from Channel 9 was $194.75-159.3=35.45$ Mc/s, which was within the vision channel i.f. pass band of 34.65-37.15 Mc/s. It thus produced a beat of $35.45-34.65=0.8$ Mc/s with the Channel 1 intermediate frequency and a corresponding bar pattern on the picture.

This effect was experienced in a district near Alexandra Palace where the Band III signal is relatively weak. It would obviously be more likely to occur near the Channel 9 transmitter where the conditions would be reversed. It should be emphasized that the equipment used was experimental and that no difficulty was found in overcoming the interference. At the time an r.f. coupling circuit effective in both bands was being used as a temporary measure, so that the tuner had only one effective signal circuit to discriminate against the effects. Most commercial sets have tuners with three such circuits and conditions would have to be very unfavourable for it to occur with these.

Manufacturers' Products

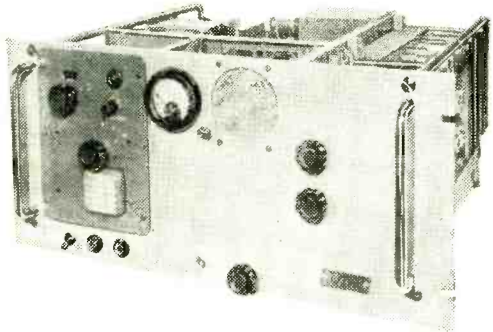
NEW EQUIPMENT AND ACCESSORIES FOR RADIO AND ELECTRONICS

New Single-sideband Receiver

THE receiver illustrated is the Racal Type RA9 which has been developed in conjunction with the R.A.E., Farnborough, for ground use in ground-to-air single-sideband radio-telephone communication in the frequency band 2.5 to 20 Mc/s.

Frequency control of the carrier re-insertion oscillator is facilitated, first, by employing a temperature-stabilized crystal oscillator and, secondly, by not entirely suppressing the carrier, but radiating one with an amplitude inversely proportional to the average depth of modulation. Thus in the absence of modulation the carrier is radiated at maximum transmitter power and reduced to a low level with full modulation. This system provides a strong, but intermittent, signal for operation of the a.f.c. circuits in the receiver.

The advantages claimed for single-sideband operation are: improved signal/noise ratio (about 9 db), freedom from selective fading and cross modulation and more economical operation of the transmitter. Some features of this particular receiver are: sensitivity 1 μV input for 25 db signal/noise ratio up to 10 Mc/s and 20 db over; unwanted sideband rejection better than 55 db; a.f.c.



Racal Type RA9 single-sideband receiver for ground-to-air communications in the band 2.5 to 20 Mc/s.

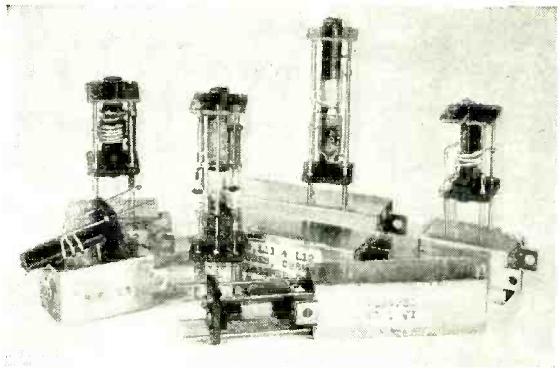
capture range (deviation from nominal transmitter frequency over which control is effective) 600 c/s with filter in and 3 kc/s without; a.f. output 2 watts (for 2.5% distortion) with 3 or 15 ohms load and 1 mW into 600 ohms load for P.O. lines. A self-contained monitor loudspeaker is operated at about 0.25 W.

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

F.M. Tuner Coils

A SET of six coils for the f.m. tuner described by S. W. Amos and G. G. Johnstone in our April and May issues this year is now obtainable from Copy Windings, Healey Lane, Batley, Yorkshire, the price being 47s 6d. They are wound on the specified sizes and types of former with all windings correctly dimensioned and securely fixed in position.

The ratio detector transformer, together with two GEX34 crystal diodes and capacitors C_{28}, C_{30}, C_{31} and C_{32} are neatly packed into a $\frac{13}{16}$-in square can measuring $2\frac{3}{8}$in high. The two i.f. transformers are assembled in the same size of can and the capacitors C_{20}, C_{21}, C_{24} and



Set of coils for WIRELESS WORLD *F.M. Tuner made by Copy Windings.*

C_{25} are actually of closer tolerance than specified, being ±2%, which is all to the good.

Oscillator, r.f. and aerial coils are each housed in $\frac{13}{16}$-in square cans $1\frac{3}{8}$in high, and in the samples sent to us C_1 was included with L_1 and L_2, but C_9 was omitted from the oscillator assembly.

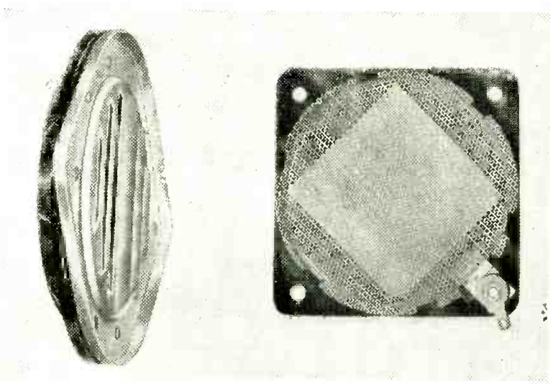
Electrostatic "Tweeters"

DESIGNED for frequencies from 5 to 20 kc/s, the LSH75 loudspeaker unit is of the two-electrode type with a gold-sputtered polythene diaphragm and perforated metal fixed plate. It measures 3in × 3in × $\frac{1}{4}$in and weighs $1\frac{1}{4}$ ounces. Normally it is connected to the anode of the output stage through a simple high-pass R-C filter and is polarized from the h.t. supply (max. working voltage 300). The capacitance is 800pF and the power-handling capacity in the designed frequency range is up to 6 watts.

For powers up to 10 watts, the LSH100 is recommended by the makers. This measures 5in × 4in × $\frac{3}{4}$in and is enclosed in a composite metal and plastic case with louvres for the sound outlet; the weight is $3\frac{1}{2}$ ounces.

The price of the LSH75 is 12s 6d and of the LSH100, 21s. The units are handled by Technical Supplies Ltd., 63 Goldhawk Road, London, W.12.

Type LSH75 and (right) LSH100 electrostatic loudspeakers.



MICROWAVE HARBOUR BEACON

Navigational Aid Using Transistors for Small Craft

By A. L. P. MILWRIGHT*

THE beacon described here was developed for the Ministry of Transport and Civil Aviation by the Admiralty Signal and Radar Establishment as an aid to entering harbour in bad visibility for craft which are too small to carry a standard marine radar, such as are found in the herring drifter fleet. The system is an adaptation of the old Lorenz type of landing aid for aircraft and consists of a 3-cm radar type transmitter mounted at a harbour entrance and radiating from two aerials which have overlapping beams. The transmitter is so sited that the line of intersection of the two beams is along the safe course line for entering harbour, as shown in Fig. 1. The transmissions consist of pulses of approximately 0.25 μsec duration with a repetition rate of 1,000 p.p.s. The output of the transmitter is switched in turn to each of the aerials in such a sequence that the morse letter B (— · · ·) is transmitted from one aerial and the morse letter V (. . . —) from the other aerial. The characters of one letter are transmitted during the period of the space intervals between the other letter with the result that along the line of intersection of the two beams where the amplitude of the signals from each aerial is equal, a continuous signal is received as is shown in Fig. 2.

The shore-based transmitter and modulator unit are mounted immediately behind the aerial (Fig. 3) and consist of a free running blocking oscillator (CV73) which produces a 0.3-μsec pulse at 1,000 p.p.s. This is cathode coupled to a hard valve modulator (CV73) the output of which is capacity coupled to a magnetron (M503). The magnetron delivers a pulse of 0.25 μsec duration with a peak power of 7 kW and the output is fed to each of two aerials in turn *via* a waveguide switch. This switch consists of an H-plane four-arm cross junction with a vane mounted across the junction at 45°. In order to switch the power to each aerial in turn, the vane is pivoted about the centre of the junction through 90° by a solenoid and lever arm, and the solenoid is energized *via* a pair of contacts and a cam driven by a small synchronous motor. The cam is cut to operate the solenoid in the time sequence . . . — The fourth arm of the switch is terminated in a short circuit to absorb any leakage past the vane into the other aerial. A monitor of the power output is provided by a meter and thermistor bridge which is coupled to the magnetron output by a waveguide directional coupler.

The aerial consists of two vertical 2ft 6in linear resonant slot arrays mounted at one end and on each side of a separator plate measuring 4ft × 3ft. The horizontal radiation diagram consists of two lobes each 60° wide overlapping over a narrow sector.

* Admiralty Signal and Radar Establishment.

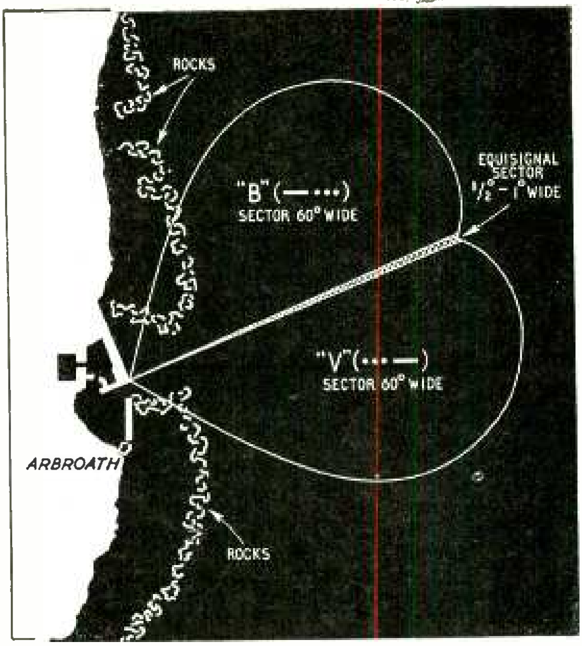


Fig. 1. Approximate coverage of the microwave harbour beacon showing the narrow equi-signal course path.

Fig. 2. The equi-signal course path arises from the overlapping of the B and V morse signals radiated by the two aerials.

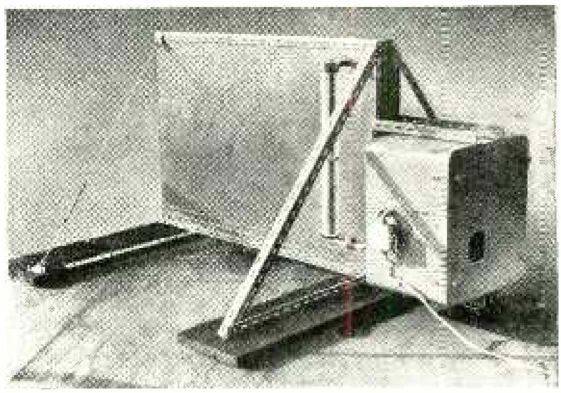


Fig. 3. Transmitter and aerial system (only one aerial visible) of the microwave beacon.

The system involves an amplitude comparison between the transmissions from each half of the aerial and since the ear cannot detect changes in amplitude of less than 1db the effective angular width of the equi-signal sector is 1°. The vertical beam width is 2.6°.

The ship's receiver is a wide-band pre-tuned crystal receiver coupled to a small horn aerial having hori-

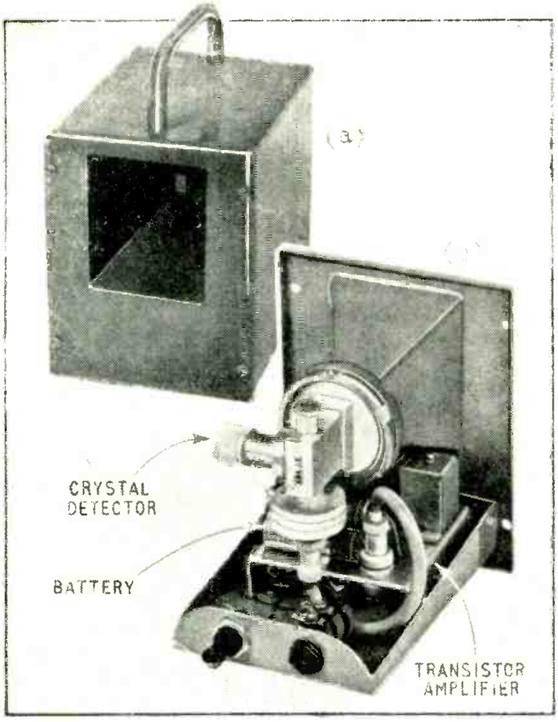
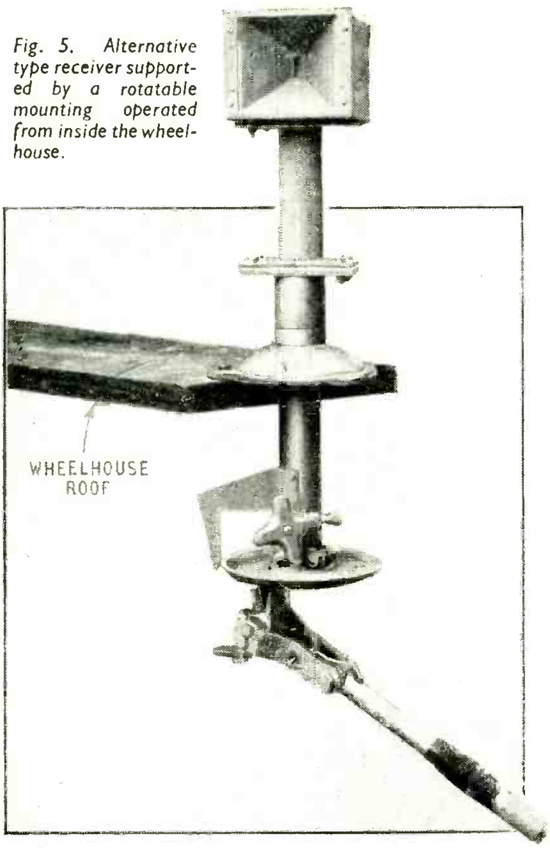


Fig. 4. The ship's receiver showing (a) the complete set and (b) chassis (with horn) removed from the case.

Fig. 5. Alternative type receiver supported by a rotatable mounting operated from inside the wheelhouse.



zontal and vertical beam widths of 25°. The receiver and its power supplies are built around the horn and measure 4in × 5in × 5in (Fig. 4a and b) and weigh 4½lb. The receiver's amplifier has a gain of 84db and uses four junction type transistors. The overall sensitivity is 10^{-8} watts, and reception is by means of headphones. The power supplies are provided by a 4½-volt flashlamp battery and the current drain is 5 mA. An improved model of the receiver (Fig. 5) incorporates a horn having a horizontal beamwidth of 16° and it is supported on a rotatable searchlight mounting. This is intended for fitting through the wheelhouse roof of a small boat. The output of this receiver is brought out to a 'phone jack on the rotating arm into which a loudspeaker attachment may be plugged. The loudspeaker is a 3½in dia type and it is driven by two 100-milliwatt transistors in push pull.

Trials and demonstrations have been carried out at Frazerburgh and Arbroath and the equipment operated very satisfactorily out to a range of approximately seven miles.

[*A commercial version of the microwave beacon described is, we understand, being made by Elliott Bros., Ltd.*—Ed.]

Record and Stylus Wear

INCREASING the weight on a stylus point in contact with a record reduces the pressure. This apparent paradox is resolved when it is realized that plastic yielding of the record material increases the area of contact at a greater rate than the increase of force causing the deformation.

This point is made early in a paper by F. V. Hunt in the *Journal of the Audio Engineering Society* (Vol. 3, No. 1, January 1955) "On Stylus Wear and Surface Noise in Phonograph Playback Systems." Prof. Hunt makes a detailed mathematical analysis of the stress contours under a spherical indenter in contact with the plane surface of a plastic material and sets out the conditions for the onset of plastic yielding. This is influenced by the size of the point to the extent that a perfect specimen of a material, without flaws such as crystal lattice imperfections, has considerably greater strength, and the probability of finding such a specimen under the contact increases as its size is reduced. This effect is observed in the results of "micro-hardness" indentation testing of materials, and may account for the fact that microgroove records are not excessively damaged in spite of the fact that the 2:1 reduction in recommended playing weight reduction as compared with standard records is only half what is should be (the stylus *force* must vary directly as the square of the stylus radius to maintain constant stylus *pressure*).

The theory is extended to the case of real surfaces making contact only at a few high points or asperities, and it is shown that on this scale plastic yield is intermittent and accounts for much of the surface noise. A discontinuity in the load/wear curve of a stylus exists at low loading and spectacular increases in the life of records and styli can be expected if, for example, the playing weight on a point of 0.001 inch radius is reduced below 2 grams.

The rupturing of bonds of adhesion at points of contact between local asperities on the stylus and record groove surface is thought to account for the present irreducible minimum of surface noise. These bonds are often as strong as the cohesive forces of the materials themselves and the shear stresses required to break them combine to give the coefficient of friction of the material.

Choice of materials having low inter-facial adhesion (and a low coefficient of friction) should, on this argument, have very low surface noise, and the suggestion is made that "Teflon" (polytetrafluoroethylene) might be tried as a record material.

NOVEMBER MEETINGS

Institution of Electrical Engineers

Radio and Telecommunication Section.—November 3rd. "The new high-frequency transmitting station at Rugby" by C. F. Booth and B. N. MacLarty.

November 9th. "A transistor digital fast multiplier with magneto-strictive storage" by Dr. G. B. B. Chaplin, R. E. Hayes and A. R. Owens.

November 15th. "An electrolytic-tank equipment for the determination of electron trajectories, potential and gradient" and "A method of tracing electron trajectories in crossed electric and magnetic fields" by Dr. D. L. Hollway to be read by Dr. J. H. Westcott.

November 21st. Discussion on "The reception of Band I and Band III television programmes" opened by E. P. Wethey.

November 29th. "The specification of the properties of the thermistor as a circuit element in very-low-frequency systems" and "A vector method for amplitude-modulated signals" by Dr. C. J. N. Candy.

All the above meetings will be held at Savoy Place, London, W.C.2, at 5.30.

Cambridge Radio and Telecommunication Group.—November 8th. Address by H. Stanesby (Radio Section chairman) at 8.15 at the Cavendish Laboratory, Cambridge.

North-Eastern Centre. — November 14th. "A Transatlantic Telephone Cable" by Dr. M. J. Kelly, Sir Gordon Radley, G. W. Gilman and R. J. Halsey at 6.15 at the Neville Hall, Newcastle-on-Tyne.

North Midland Centre.—November 1st. "A Transatlantic Telephone Cable" by Dr. M. J. Kelly, Sir Gordon Radley, G. W. Gilman and R. J. Halsey at 6.30 at the Central Electricity Authority, 1, Whitehall Road, Leeds.

North-Western Radio and Telecommunication Group.—November 9th. "High-speed electronic-analogue computing techniques" by Dr. D. M. MacKay at 6.45 at the Engineers' Club, Albert Square, Manchester.

North Scotland Sub-Centre.—November 9th. "Thermionic valves of improved quality for Government and industrial purposes" by E. G. Rowe, P. Welch and W. W. Wright at 7.0 in the Electrical Engineering Dept., Queen's College, Dundee.

South Midland Radio and Telecommunication Group.—November 28th. "A radio position fixing system for ships and aircraft" by C. Powell at 6.0 at the James Watt Memorial Institute, Great Charles Street, Birmingham.

Reading District.—November 28th. "The physics of transistors" by Dr. E Billig at 7.15 at the George V Room, George Hotel, King Street, Reading.

Tees-side Sub-Centre. — November 2nd. "The Manchester-Kirk o'Shotts television radio relay system" by G. Dawson, L. L. Hall, K. G. Hodgson, R. A. Meers and J. H. H. Merriman at 6.30 at the Cleveland Scientific and Technical Institute, Middlesbrough.

Graduates' and Students' Section.—November 2nd. "Communication of information—human, animal and machine" by Dr. E. Colin Cherry at 6.30 at Savoy Place, London, W.C.2.

November 15th. "An introduction to the transistor" by A. V. Bryant at 7.0 at R.E.M.E. Training Centre, Bailleul Barracks, Arborfield, Berks.

November 29th. "Colour television" by L. A. Harris at 7.0 at the Public Library, Chelmsford.

British Institution of Radio Engineers

London Section.—November 30th. "High-fidelity loudspeakers—the performance of moving-coil and electrostatic transducers" by H. J. Leak at 6.30 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

Merseyside Section.—November 9th. "The Decatron tube in a digital transmission system" by G. Shand at 7.0 at the Chamber of Commerce, Old Hall Street, Liverpool, 3.

North-Eastern Section.—November 9th. "Turret tuners for multi-channel television reception" by R. Holland at 6.0 at Neville Hall, Westgate Road, Newcastle-upon-Tyne.

North-Western Section.—November 3rd. "Ground controlled approach and instrument landing system" by R. H. James and N. MacKinnon at 7.0 at the College of Technology, Sackville Street, Manchester.

Scottish Section.—November 10th. "Some applications of electronics to marine echo-sounding" by F. Baillie at 7.0 at the Institution of Engineers and Shipbuilders, 39 Elmbank Crescent, Glasgow, C.2.

British Sound Recording Association

London.—November 18th. "The development of professional recording equipment" by W. S. Barrell at 7.0 at E.M.I. Studios, 3 Abbey Road, N.W.8.

Television Society

London.—November 11th. "The application of semi-conductor diodes to television circuits" by J. I. Missen.

November 24th. "Interference with television reception: its causes and cures" by R. A. Dilworth.

Both meetings are to be held at 7.0 at 164, Shaftesbury Avenue, W.C.2.

Physical Society

Acoustics Group.—November 11th. "Acoustic interferometers" by Dr. E. G. Richardson at 5.30 at Imperial College, South Kensington, London, S.W.7.

British Kinematograph Society

London.—November 23rd. "The display of television pictures in the home" by E. P. Wethey at 7.15 at the Gaumont-British Theatre, Film House, Wardour Street, W.1.

Radio Society of Great Britain

London.—November 11th. "Compressed beams" by G. A. Bird (G4ZU) at 6.30 at the I.E.E., Savoy Place, W.C.2.

DO YOU KNOW?

HOW long the elements for a Band II or Band III aerial should be?

Where to apply for a licence to establish a mobile radio-telephone link?

What value of resistors to use for a television attenuator?

The address of each of the above societies?

The base connections for a PCF80?

The answers to these and very many other radio technical and organizational queries can be readily given by the owner of a *Wireless World* Diary. The 1956 edition—the 38th—is now obtainable from booksellers and newsagents, price 5s 10d (morocco leather) or 4s 1d (rexine).

In addition to the 80-page reference section, which includes details of base connections for 600 valves, there are the usual week-at-an-opening diary pages.

RANDOM RADIATIONS

By "DIALLIST"

Band III Aerials

INGENIOUSLY designed Band III and two-band aerials continue to appear and I expect there'll be lots more new ideas in months to come. Amongst the earliest to make their bow were the J-Beam single-slots and slot-beams for Band III. As "ghosting" is one of the big problems in that band the slot, either as a "single" or with reflector and directors, should be a help to good reception in difficult places. All kinds of clip-on attachments are being produced for converting a Band I aerial for two-band operation. Many will be useful only if the B.B.C. and I.T.A. transmitters lie in the same direction from the viewer. But there are also several clever ideas for enabling the two arrays to be oriented independently. One that interests me is the Antiference "electronic coupling." An arm carrying the desired number of Band III elements and the Band I dipole, critically spaced from the nearest of these, is mounted on the mast and turned in the direction of the I.T.A. station. A second arm carries the Band I reflector and can be swung so that it and the dipole are directed towards the B.B.C. station. Both arrays are thus properly oriented and only a single feeder, in which both signals appear, is needed.

Exhibition Prefabs?

THE bright suggestion has been made that stands for future wireless shows should be prefabricated. The idea is that each exhibitor would make his own stand in sections. Every section would be completely wired and the stand would be erected by the simple process of putting the sections in their right places and plugging each section into the next. All the wiring would terminate in a single heavy-duty plug and only one main electrical connection would then be needed for any stand. It seems quite a brilliant idea; but one wonders what kind of reactions it would provoke!

Lighting or Power?

A STORY came my way the other day which was declared to be true by its teller. It might well be, for there's no end to man's (and woman's) ignorance and folly about things electric. Anyhow, here it is. Into an electrical dealer's shop walked a man who had just moved into a house in the neighbourhood. "There are some wiring changes and additions that I want made," he said, "and I'd be glad if you'd take on the job." The dealer having replied suitably, his visitor went on: "Oh, by the way, could you lend me an ammeter for about half an hour?" Asked what he wanted it for, he replied that there were a good many sockets in the house and he wasn't quite sure which of them were for lighting and which for power. "But how will the ammeter help you?" "Oh, don't you know? It's quite simple. You just put the prods into the socket: if it's for lighting the meter reads 5 amps; if for power it reads 15."

Needlessly Scrapped

ONE of the things I'd like to know (though it's not likely that I or anyone else ever will) is the number of television c.r. tubes perfectly capable of giving good service that are scrapped in a given year. It would most certainly run to a largish figure. The two main causes of unnecessary replacement are cathode-to-heater shorts and low emission. Nothing can be done about the first of these if the mains supply is d.c. but if it is a.c., fitting an inexpensive isolating transformer for the heater puts things right. The owner of a c.r. tube with low emission has to take a chance if he's on d.c.; reactivation by running the cathode at high temperature for brief periods may be successful and give the tube a further lease of life, but it may also mean a burnt-out heater. It's a chance worth taking anyhow, for an otherwise useless tube may last for months if the reactivation is successful. The a.c. man can usually count on good results. All that he needs is a booster transformer for the heater. I know one c.r. tube which still gives an excellent picture 18 months after the fitting of a booster.

Steps Forward

AMONGST the improvements one has so far noticed this year in TV receivers is the increased adoption of flywheel sync. This should lighten the lot of viewers who live in places where interference of certain kinds is bad and those whose homes are in fringe areas with a poor signal-to-noise ratio. Another welcome improvement is the wider use of effective automatic gain control. It seems to me, too, that a good many new sets are making a better job of interlacing than did some of their predecessors. But I must say I'd like to see more rather than less genuine a.c.-only television sets with double-wound mains transformers in their power-packs. Diehard or not, I'll never become reconciled to the transformerless receiver, worked as it is more often than not from a two-point a.c. mains socket.

CLUB NEWS

Barnsley.—At the meeting of the Barnsley and District Amateur Radio Club on November 11th, W. Williams will speak on "Band II f.m. reception." A fortnight later F. Robinson (G3FLQ) will describe a superhet double conversion adaptor. Meetings are held at 7.0 at the King George Hotel, Peel Street, Barnsley. Sec.: P. Carbutt (G2AFV), 33 Woodstock Road, Barnsley, Yorks.

Birmingham.—The annual dinner of the Midland Amateur Radio Society will be held at the Imperial Hotel, Birmingham, on November 12th. Sec.: C. J. Haycock, 360 Portland Road, Edgbaston, Birmingham, 17.

Cambridge.—The Cambridge University Wireless Society (G6UW) meets at 8.15 each Tuesday of the full term in the Cavendish Laboratory. Sec.: A. Brunnschweiler, Pembroke College, Cambridge.

Cleckheaton.—During November the Spen Valley and District Radio and Television Society will be visiting the psychology department and seeing the electron microscope at Leeds University (2nd) and the medical physics department of the General Infirmary, Leeds (30th). On the 29th Mullard films will be shown at the Metropole Hotel, Leeds. Meetings commence at 7.30. Sec.: N. Pride, 100 Raikes Lane, Birstall, Nr. Leeds.

Edinburgh.—The first of a series of talks describing "A Beginner's Transmitter" will be given on November 3rd to members of the Lothians Radio Society. On the 17th J. W. Kyle (GM6WL) will deal with 70-cm reception. Meetings are held at 7.30 at 25 Charlotte Square, Edinburgh, 2. Sec.: J. Good (GM3EWL), 24 Mansionhouse Road, Edinburgh, 9.

Southend.—At the meeting of the Southend and District Radio Society on November 11th, H. Wilkinson will talk on "Current trends and developments in radio and television." On November 25th a representative of the Automatic Coil Winder Company will speak on 'Recent developments in test equipment for the electronic industry." Meetings are held at 7.15 at the Ekco Works, Southend-on-Sea. Sec.: P. C. Baldwin, 13 Inverness Avenue, Westcliff-on-Sea, Essex.

Swindon.—Regular meetings are now being arranged for the recently formed Swindon Amateur Radio Club, of which R. Reynolds (G3IDW) is chairman. Weekly classes of instruction in preparation for the amateur radio examination are being held at the College, Swindon, at which the instructor is G. R. Pearce (G3AYL), who is secretary of the club. His address is 102 Kingshill Road, Swindon, Wilts.

UNBIASED

By FREE GRID

Electronic Tapostat

IN the August issue of *Wireless World* the Editor demanded the invention of an electronic "bookmark" or tapostat for tape recorders so that a user could rapidly wind-on or rewind the tape until he found the particular section he desired to play.

Naturally, I replied by return of post detailing a scheme. This provided for the tape to have supersonic frequencies imposed on it at selected spots during recording. The great increase in tape speed on fast wind or rewind would naturally convert such supersonic frequencies into radio frequencies. These could be picked off the tape by a tuned r.f. head, amplified, rectified and used to actuate a relay-operated brake which would stop the mechanism at any desired spot on the tape.

The Editor rejected my idea on the ground that it was several years in advance of its time. Those were not his exact words but they were certainly implied in his answer. He told me that our sound-recording tapes have too noisy a background for my idea to succeed. It cannot be doubted, I think, that in time all tape recordings will have the same silent background as the tapes being used in the experiments for the recording of television and then, of course, my electronic tapostat will come into its own.

"Walter, Lead Me to the Altar"

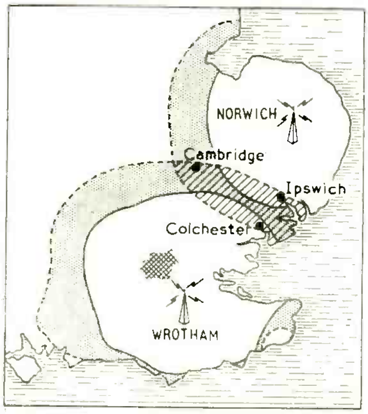
READERS of *Wireless World* will have heard of Dr. Grey Walter of encephalograph fame and be familiar with his important work in the field of neurological diagnosis and kindred subjects.

According to some sections of the daily press, however, Dr. Grey Walter has now started to trespass on the prerogatives of Madame Estelle by warning us of matrimonial pitfalls ahead. To give him his due, however, his matrimonial soothsayings, unlike those of Madame Estelle, are founded on the solid rock of science. He does not tell girls to beware of the buccolingual blandishments of sinister dark-haired men of the "Sir Jasper" type. Instead he advises them to demand that any would-be Romeo should produce his encephalogram.

Dr. Grey Walter advises that only those with compatible encephalograms should launch out together on the stormy seas of matrimony. It would seem advisable for all budding benedicks of either sex to carry around with them, like a passport, their personal encephalograms, duly authenticated by Dr. Grey Walter and his colleagues. Thus girls of the future will have as their theme song the same ditty which was so popular among their Edwardian sisters but with a slightly different meaning; "Walter, Lead me to the Altar."

Bi-Fi

IN my opinion the outstanding audio feature of 1955 has been the introduction by more than one firm of



East Anglian 2-channel broadcasting

stereophonic reproduction from records. The name "stereophonic," or any of its obvious variations, is rather a mouthful, however, and I think, following the tendency of modern jungle jargon, a better name would be bi-fi. The whole *raison d'être* of the thing is that it is not only binaural—for all listening is that—but "bi" everything else as two channels must be used throughout. It is also bi-fi in the hellenic sense of "bi," for the music and everything else does indeed appear to be living.

In view of the great success of recent bi-fi demonstrations, I hope that the director of technical services at the B.B.C. now takes a more enlightened view of bi-channel broadcasting than he did in his letter to *Wireless World* a few years ago (April, 1950). When the Norwich v.h.f. station opens in 1956 he will have a unique opportunity of experimenting with bi-fi.

According to the B.B.C.'s published map, those living between Ipswich and Colchester and in a corridor extending west beyond Cambridge will be able to receive both the Wrotham and Norwich transmissions. To make matters quite clear I reproduce part of the v.h.f. map on which I have shaded-in the corridor.

One or more of the three transmitters at these two stations will always be radiating the same programme and it will, therefore, be possible to experiment with bi-fi in that area at a minimum of expense as it would only be necessary for the B.B.C. to use separate mikes and associated gear to feed the two chosen transmitters. It could at least be tried out with the two transmitters radiating the Third Programme where bi-fi would be most appreciated. What about it, Sir Harold?

Strabismogenic TV

THE size of the screen in domestic television receivers has been growing steadily during the past few years to such an extent that many of the latest sets seem only suitable for baronial halls. Unfortunately the feeling that they must "keep up with the Joneses" forces people into the same foolish competition of "bigness" in which they once indulged in sound radio, when it seemed everybody's wish to compete with the bulls of Bashan.

To attempt to view some of these huge screens in the confines of an ordinary room leads only to strabismus, as I found out the other day when invited to a friend's house to view his latest "horror-scope." Eventually people will learn common sense as they did with sound radio.

Now even with a 17-in screen, lines are painfully evident. One or two firms do provide spot wobble in this and larger sizes but it is high time something was done about this problem, by the radio industry in general, without resorting to the drastic remedy of altering the British standard of 405 lines.

The disadvantages and complications of this latter remedy have been

405 hard lines

pointed out more than once in this journal, but surely it is not beyond the wit of our technological tycoons to tackle this problem with the same vigour and success as women remove the lines from their faces.