Wireless World

ELECTRONICS, RADIO, TELEVISION

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FEBRUARY 1956

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Practical Uses of "Scatter"

UNTIL quite recently, long-distance communication was not considered possible on frequencies higher than about 30 Mc/s. It was thought that, on these higher frequencies, the so-called "space-wave" would constitute the only useful part of the emitted radiation, and that attainable ranges would be limited to a distance only slightly beyond the horizon. But now it has been found possible, by making use of the phenomenon of "scattering," to extend the range of transmission, in both the v.h.f. and u.h.f. bands, to distances far beyond the horizon; in fact, to establish reliable communication systems over ranges of 200 to 1,200 miles.

There are two distinct systems of scatter transmission, both of which have been discussed in our pages. To recapitulate, the first makes use of a scattering region existing in the lower part of the ionospheric E layer. By the use of highly directional transmitting and receiving aerials, each trained upon a selected area of the scattering region, a usable signal is produced up to distances of 1,200 miles. This communication system is most effective on frequencies in the lower v.h.f. range (of the order of 50 Mc/s). The advantage of this system is that it is largely independent of the ionospheric vagaries which afflict h.f. communications; no frequency changing is necessary and it is not affected by ionospheric disturbances. Its main disadvantages are that it is essentially a narrow-band system, and so will not carry high-quality telephony or television signals. All the same, it is easy to see that the method has many possibilities. It could provide many new channels for telegraphy and perhaps for speech-quality telephony, thus supplementing the overcrowded channels in the h.f. bands. Given the necessary international co-operation, chains of v.h.f. scatter stations could, by spanning the oceans in island-to-island hops, link together the main land masses of the world.

The second system depends on scattering from a region which exists in the lower atmosphere by virtue of air turbulences which are always present there, and which constitute the scattering centres. Again, highly directional transmitting and receiving aerials must be aimed at a common scattering area, but in this case, as the area is at a lower level, the maximum range attainable is shorter, being of the order of 200 miles. Here the usable frequencies are in the u.h.f. band, from 500 Mc/s upwards. Successful American experiments have been carried out on about 900 Mc/s. According to reports, the method has been used in the U.S.A. for the transmission of 12 speech-frequency channels and for television. Indeed, the width of the band covered is the great advantage. The most obvious use for u.h.f. scatter is for the international exchange of television programmes; by its use, many costly cable circuits and chains of closely spaced relay stations could be eliminated. For example, it should just be possible to transmit television signals directly between Paris and London without any intermediate relaying. Eventually, a world-wide exchange of television programmes should become at least technically possible. It would seem over-optimistic, though, to suggest at present that Europe and the United States could be linked for television exchanges, at least by the direct westerly route.

In America, where much work has already been done on scatter propagation, it has been forecast that the new techniques will fill a gap in providing reliable communication at distances between, very roughly, 100 miles and 1,000 miles. The lower limit is too long for normal v.h.f. or u.h.f. line-of-sight propagation, while the upper is considered too short for reliable h.f. working *via* the ionosphere. "Reliable" is here the operative word; the scatter system has yet to prove itself over extended tests in different parts of the world. It may well prove to be more reliable than ionospheric h.f. transmission for working over notoriously difficult signal paths.

An objection sometimes put forward on economic grounds is that the aerials needed for the scatter system are costly and that transmitting powers are high. Against this, it may be urged that transmitters and aerials are inherently cheaper than those for l.f. stations, which have, in the past, succeeded in paying their way—indeed, they are still in use for special purposes. The scatter system has been described as inelegant, but there is little doubt it will eventually be developed into an important supplement to existing communications resources.

DISTORTION IN Electrostatic Loudspeakers

CONDITIONS NECESSARY FOR LINEAR OPERATION

AFTER holding undisputed supremacy for a quarter of a century the moving coil principle of drive for loudspeakers must now meet growing competition from the electrostatic principle, which has been shown to be capable of intrinsically better performance from the point of view of non-linearity distortion.

Basic Formulæ

$$Q = CV = \frac{\kappa AV}{d}$$

$$C = \frac{\kappa A}{d}$$

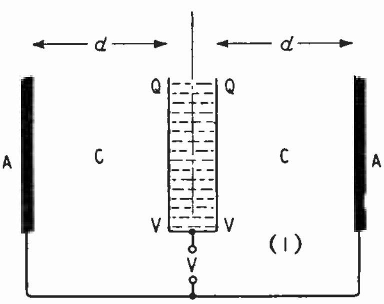
$$V = \frac{Qd}{\kappa A}$$

$$F = \frac{QV}{2d} = \frac{\kappa AV^2}{2d^2}$$

Recent articles [1, 2, 3] have reviewed the theoretical basis and given some pointers to the practical requirements for the realization of low distortion levels. The material presented was voluminous and to those readers who remember the Vogt loudspeaker[4] of the late '20s may not have seemed to include any new feature. Like the latest designs it operated on the push-pull system with a polarizing voltage applied through a resistance to a thin diaphragm supported midway between perforated metal plates, to which the signal was applied "differentially" (i.e., in push-pull).

This form of construction gave a marked improvement over the single fixed plate electrostatic loudspeaker, but non-linearity due to the increased force as the diaphragm approached either of the two fixed plates was acknowledged and to some extent compensated by adjustment of the elasticity and diameter of the diaphragm.

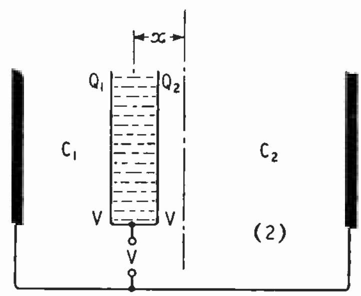
This non-linearity arises because the force acting on the diaphragm, which is always zero in the mid position, increases when the diaphragm is displaced —except in one particular set of circumstances, which we shall discuss later. The displacement need not be due to the applied signal voltage and can be mechanical. It is, in fact, convenient at this stage to forget the effect of the signal and to concentrate only on the stability of the diaphragm under the influence of the polarizing voltage alone, for if there is a non-linear force already in action the signal can only add to it.



$$F = \frac{\kappa AV^2}{2d^2} - \frac{\kappa AV^2}{2d^2} = 0$$

(1) Conducting diaphragm, mid position, directly connected

Some useful basic electrostatic formulæ are given in the accompanying panel, and if we apply them to the four diagrams we should be able to see why some electrostatic loudspeakers distort and others do not. The formulæ assume the use of rationalized MKS units and that κ=total permittivity of the space between electrodes, A=area of electrodes,



$$F = \frac{\kappa AV^2}{2(d-x)^2} - \frac{\kappa AV^2}{2(d+x)^2} = \frac{2\kappa AV^2dx}{(d^2-x^2)^2} \qquad Q_1 = \frac{\kappa AV}{(d-x)} \qquad Q_2 = \frac{\kappa AV}{(d+x)}$$

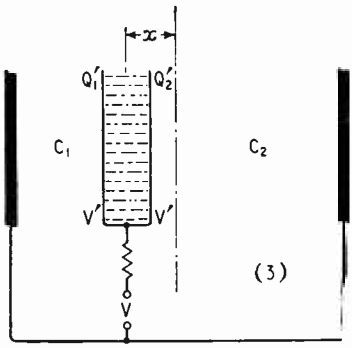
(2) Conducting diaphragm, directly connected and displaced from mid position

C=capacitance, Q=charge, V=voltage and F=force. The thickness of the central diaphragm has been exaggerated so that the existence of conductivity between the two surfaces can be shown by horizontal shading.

Diagram (1) represents a diaphragm exactly centred between the fixed plates with a polarizing voltage V, which will be the same on both sides, since the diaphragm is a conductor. The capacitance on both sides is the same, so the charges will also be equal. While the diaphragm remains central it will experience no resultant force.

In diagram (2) the diaphragm has been displaced a distance x. Both faces are still at the same potential, but the capacitances on each side are unequal and there must be a redistribution of charge. There

[1] A. A. Janszen. *Journal Acoustical Engineering Society*, Vol. 3, No. 2, April, 1955.
[2] P. J. Walker, *Wireless World*, May, June, August, 1955.
[3] H. J. Leak, *The Gramophone*, May, 1955.
[4] *Wireless World*, 12th September, 1928, p. 309 and 29th May, 1929, p. 553.
[5] *Wireless Engineer*, May, 1955, p. 119.



$$\kappa A V'\left(\frac{1}{d-x}+\frac{1}{d+x}\right) = Q'_1+Q'_2 = 2Q$$

$$V' = \frac{2Q}{\kappa A\left(\frac{1}{d-x}+\frac{1}{d+x}\right)}$$

$$F = \frac{\kappa A}{2}\left(\frac{1}{(d-x)^2}-\frac{1}{(d+x)^2}\right)\frac{4Q^2}{\kappa^2A^2\left(\frac{1}{d-x}+\frac{1}{d+x}\right)^2}$$

$$= \frac{2Q^2x}{\kappa Ad}$$

(3) Conducting diaphragm, displaced and fed through a high resistance (constant total charge)

is a resultant force on the diaphragm which does not vary linearly with the displacement x.

So far we have assumed that the conducting diaphragm is directly connected to the polarizing source and that current can flow to make up the change of Q necessary to satisfy the equation $Q=CV$ when V is kept constant and C is changed. Under these conditions (Q_1+Q_2) will never be less than 2Q.

If a resistance is inserted between the source and the diaphragm it will not affect the conditions (2) if the time constant it forms with C_1 and C_2 is short compared with a half-cycle of the applied signal; this condition is satisfied by the values which were used for safety resistances in the early electrostatic loudspeakers.

When the series resistance gives a time constant long compared with a half period of the lowest audio frequency the charge on the diaphragm cannot change appreciably from its average value $(Q_1'+Q_2') \approx 2Q$, so when displaced the potential of the diaphragm must fall to a new value V', diagram (3). But, and this is the important point, the charges on each side of the diaphragm will still be dissimilar; and, although we are now working under "constant total charge" conditions there is still a force due to the polarizing voltage when the diaphragm is displaced. This force is linear with displacement, but is not due to the signal and is, therefore, a distortion.

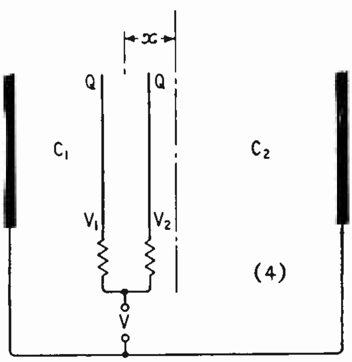
W. T. Cocking has shown[5] that all unwanted forces will disappear only when the two faces of the diaphragm are insulated from one another. Under these conditions, with no possibility of migration of charge as the result of the changes of capacitance, and with separate high resistors feeding each side of the diaphragm, it will be the potentials V_1 and V_2 which will accommodate themselves to satisfy $Q=CV$. With voltage varying directly with electrode spacing we now have exact compensation and there will be no force due to the polarizing voltage, irrespective of the position of the diaphragm, (4).

Having disposed of the forces both linear and non-linear arising from the presence of the charge itself, the force due to the establishment of an additional signal field between the two outer fixed plates may be considered separately and unhindered. This is simply the product of the charge and the field strength due to the signal and is independent of the position of the charge in the field.

The object of this note has been to point out that a series resistance will not by itself linearize the electrostatic loudspeaker; the diaphragm must be an insulator so that the migration of the charge between faces is prevented—at least for the duration of a half-cycle of the lowest frequency to be reproduced. If the surfaces of the diaphragm are sprayed to make them conducting, the polarizing voltage must be fed through separate high resistances to each side. A simpler practical approach would seem to be to leave the diaphragm uncoated and rely on the surface resistivity being high, but not as high as the bulk resistivity of the material.

When the electro-mechanical driving force has been linearized there still remain a number of problems for the designer, but they are far less onerous than those associated with the moving-coil drive. The light mass of the electrostatic diaphragm implies much less internally circulating energy in the form of momentum. The load is predominantly that due to the acoustic radiation resistance and the mechanical reactive component is negligible. Good transient response should therefore be easier to achieve, and because the diaphragm is being driven over the whole of its surface, variations due to "break-up" of the vibrating surface—a feature inseparable from coil-driven cone diaphragms at high frequencies—are negligible.

The only remaining problems are how to ensure adequate air loading at very low frequencies and how best to match the capacitive electrical impedance to the amplifier.



$$V_1 = \frac{Q(d-x)}{\kappa A} \qquad V_2 = \frac{Q(d+x)}{\kappa A}$$

$$F = \frac{\kappa A V_1^2}{2(d-x)^2} - \frac{\kappa A V_2^2}{2(d+x)^2}$$

$$= \frac{Q^2}{2\kappa A} - \frac{Q^2}{2\kappa A} = 0$$

(4) Insulating diaphragm, displaced, with conducting surfaces separately fed through high resistances

WORLD OF WIRELESS

Organizational, Personal and Industrial Notes and News

London Audio Fair

SOME forty manufacturers of high-quality sound reproducing equipment will be demonstrating their products at an "Audio Fair" to be held at the Washington Hotel, Curzon Street, London, W.1, on April 13th, 14th and 15th. Though there will be exhibition stands on the ground floor of the hotel, the emphasis of the show will be on demonstrations, to be given in rooms on the upper floors under conditions closely simulating those obtaining in the home. The show is being organized by a six-man committee comprising members of audio manufacturing firms.

Admission will be by invitation card, obtainable free from radio dealers, or, in case of difficulty, from London Audio Fair, 17, Stratton Street, London, W.1. Opening hours: 11.0 a.m. to 9.0 p.m.

Lancashire I.T.A.

WITHIN a fortnight of its removal from the site of the I.T.A. Lichfield station on January 31st, the Belling-Lee pilot transmitter is scheduled to be radiating from Winter Hill, Lancs. Test transmissions from G9AED on channel 9 are due to start on February 13th. Although weather conditions have delayed the completion of the I.T.A. aerial at Lichfield test transmissions using 50 kW are scheduled to begin on February 1st.

R.T.E.B. Widens Scope

FOUNDED in 1942 for the purpose of holding half-yearly examinations for the awarding of radio and television servicing certificates, the Radio Trades Examination Board has now been granted incorporation by the Board of Trade. The holding of examinations has so far been its main activity but the Board of Trade licence to dispense with the word "Limited" has been granted on the specific objects of:—

(a) the promotion of a high standard of skill and efficiency in the technique and work of persons employed or otherwise engaged as radio mechanics, technicians and tradesmen in the radio and allied trades, and

(b) to organize, hold and conduct from time to time either alone or through or in conjunction with any appropriate body, such trade tests and examinations as to the Association may be deemed necessary or expedient to test or determine the skill and efficiency of such persons in such work.

The Board comprises representatives of the Radio Industry Council, the Radio & Television Retailers' Association, the Scottish Radio Retailers' Association and the British Institution of Radio Engineers, from whose offices at 9, Bedford Square, London, W.C.1, the Board operates.

Crystal Palace Tests

IT is anticipated that within a few days of the publication of this issue, tests will start from the new B.B.C. London transmitter at Crystal Palace. The permanent vestigial-sideband transmitter, supplied by Marconi's, is already installed but a temporary 250-foot mast and aerial have been erected as modifications have had to be made to the permanent mast to accommodate the I.T.A. aerial.

News in Morse

ONE of the many sides of the work of the Central Office of Information is the daily transmission of news and comment on current affairs to British Information Centres overseas. Except for the service to North America, for which an R.T.T. (printing radio telegraph) link employing frequency-shift keying (± 200 c/s) is now used, the bulletins are sent in morse or by the Hellschreiber method.

Below, we give the latest schedule of morse transmissions, the speed of which varies from 22 to 28 words per minute.

Region	Times (G.M.T.)		Call	Freq. (Mc/s)
Distant Europe ...	Monday	0200–0430	GIQ25	5.365
	Tues. to Sun.	0300–0530		
Middle East... ...	Monday	0200–0430	GIQ29	9.380
	Tues. to Sun.	0300–0530		
Caribbean	Mon. and Fri.	1145–1315	GIB36	16.190
	Tues. to Thurs.	1215–1315		
	Mon. to Fri.	1700–1830	GIB33	13.910
South America ...	Mon. and Fri.	2015–2130	GIN31	11.645
	Mon. to Sat.	2130–2315		
	Mon. to Sat.	2330–0230	GIS27	7.780
	Monday	0030–0230		
Africa	Mon. to Fri.	0900–0930	GCB39	19.005
South East Asia ...	Sunday	1915–2115	GAY27	7.447
	Tues. to Fri.	1715–2215		
	Mon. and Sat.	1615–1715		

World's Technical Press

EACH month our sister journal *Wireless Engineer* publishes some 300 abstracts from and references to articles appearing in the world's technical press. In the preparation of these abstracts by the Radio Research Organization of the Department of Scientific and Industrial Research nearly 200 journals are regularly scanned.

The index to the 3,800 abstracts and references published in 1955 will be included with the March issue of *Wireless Engineer* published on March 5th.

An index for the years 1946-53 has recently been published by the American Institute of Radio Engineers, from whom copies are available, price $2.35. There is a special price of $1.75 for colleges and public libraries outside the United States.

NEW YEAR HONOURS

Air Commodore W. E. G. Mann, C.B.E., M.I.E.E., R.A.F. (ret.), who is appointed a Companion of the Order of the Bath (C.B.), has been director-general of navigational services (civil aviation) in the Ministry of Transport and Civil Aviation for the past six years. During the war he was chief signals officer, R.A.F. Middle East, and has held several administrative telecommunications posts since joining the Ministry in 1945.

W. J. Richards, C.B.E., who is also appointed a C.B., has been director of the Radar Research Establishment, Malvern, since the amalgamation in 1953 of the Telecommunications Research Establishment, of which he was chief superintendent, and the Radar Research and Development Establishment. He joined the Royal Aircraft Establishment, at Farnborough, in 1925 and during the war was deputy director of scientific research (armament) at the Ministry of Aircraft Production.

Brigadier R. Gambier-Parry, C.M.G., director of communications in the Foreign Office, is promoted to a Knight Commander of the Order of Saint Michael and Saint George (K.C.M.G.).

Captain C. F. Booth, O.B.E., M.I.E.E., who has been promoted to Commander of the Order of the British Empire (C.B.E.), succeeded A. H. Mumford as an assistant engineer-in-chief at the Post Office two years ago. He joined the Radio Branch laboratories of the Post Office at Dollis Hill in 1923 and ultimately became staff engineer-in-charge. He is particularly well known in the international field of radio because of his participation in international conferences. He is a member of the technical sub-committee of the Television Advisory Committee and is chairman of the committee set up to advise the P.M.G. on Band III transmitter aerial siting.

C. W. Oatley, M.A., M.Sc., last year's chairman of the I.E.E. radio section, becomes an O.B.E. Since 1945 he has been a Fellow of Trinity College Cambridge, and lecturer in the engineering department of Cambridge University. For twelve years prior to the war he was a member of the staff of the Physics Department of King's College, London, and during the war was for some time in charge of basic work at the Radar Research and Development Establishment.

J. D. S. Rawlinson, B.Sc.(Eng.), M.I.E.E., who also becomes an O.B.E., has been superintendent of scientific personnel in the Royal Naval Scientific Service of the Admiralty since 1947. He is also chairman of the selection board for scientific and experimental officer class entrants to the Scientific Civil Service.

Among those appointed Members of the Order of the British Empire (M.B.E.) are **A. Bowen,** B.T-H. electronics engineering department, Rugby, **R. G. Hodges,** senior experimental officer at the Ministry of Supply's Radar Research Establishment, **G. E. Randall,** radio officer in S.S. *Scottish Hawk* (Siemens Brothers), and **D. C. Rogers,** A.M.I.E.E., section head at Standard Telephones and Cables works at Ilminster, Somerset. Mr. Bowen, who joined B.T-H. in 1922, was a member of the team formed in 1939 to develop radar equipment and has since been continually associated with the design of military radar gear. Mr. Rogers joined S.T.C. in 1939 and since the war has been at Ilminster, where he is concerned with the development of u.h.f. valves.

D. F. W. Archer, radio operator (supervisor), R.A.F. Cheadle, Staffs, and **R. A. Lenton,** wireless operator in the Falkland Islands Dependencies Survey, are among the recipients of the British Empire Medal.

PERSONALITIES

J. R. Brinkley, M.Brit.I.R.E., who is well known to *Wireless World* readers for his contributions on frequency allocations, especially with relation to mobile radio, has been appointed managing director of Pye Telecommunications, Limited, and an executive director of Pye, Limited, which he joined in 1948. He received his early training in the G.P.O. Line and Radio Department and in 1942 transferred to the Home Office where he was concerned with the development of the radio systems for the police and fire services. Mr. Brinkley is a member of the P.M.G.'s mobile radio committee as a representative of the Mobile Radio Users' Association, of which he is technical adviser.

H. K. Milward, B.Sc., A.M.I.E.E., who contributed the articles on an introduction to transistor electronics in the February and March issues last year, has retired from the Army and joined Pye Telecommunications. Major Milward, who took his degree at the Military College of Science in 1949, is joint author with Major Hallows of "Introduction to Valves," published from this office in 1953. From 1939 to 1942 he was staff officer (radar) and instructor at the Army Radar School, at Watchet. Since then he has held a number of administrative and technical posts in Royal Signals, including that of technical staff officer, School of Signals, Catterick.

Brigadier L. de M. Thuillier was recently appointed director of telecommunications, War Office, and will hold the temporary rank of major-general. For the past 18 months he has been chief signal officer, Northern Command, having previously held a similar post at the British headquarters in Egypt. He was commissioned in the Royal Signals in 1926 at the age of 21.

Professor J. R. Whitehead, B.Sc., A.M.I.E.E., who, from 1939 to 1951 was on the staff of the Telecommunications Research Establishment of the M.o.S. and has since then been associate professor of physics in McGill University, Montreal, has been appointed head of the new research laboratories of R.C.A. Victor, in Montreal.

R. H. Hammans, the new president of the R.S.G.B., recently became chief engineer of Granada TV Network, one of the I.T.A. programme contractors. He was for a few years on the staff of the International Marine Radio Company before joining the B.B.C. in 1935, where for nine years he was head of the television unit in the planning and installation department. On January 27th he will deliver his presidential address to the Society on single side-band transmission which he employs at his station G2IG.

H. T. Sayer, who has been for some years engineer-in-charge of Marconi's aeronautical radio servicing establishment, at Croydon, has retired after more than forty years' service with the company. During the last war he was an instructor at the Admiralty Signal Establishment, and before the nationalization of the airlines he was chief instructor at the Marconi radio school at Croydon. He is succeeded as engineer-in-charge at Croydon by **W. L. Munday.**

J. N. M. Legate, B.Sc., A.M.I.E.E., has been appointed assistant chief engineer in the industrial control department of Metropolitan-Vickers Electrical Company, which he joined as a college apprentice in 1931. Since 1947 he has specialized in electronic control.

D. H. Murdoch, who was recently appointed head of the telecommunications section of the Oversea Press Services Division of the Central Office of Information, was for ten years assistant superintendent on the staff of the Inspector of Wireless Telegraphy at the G.P.O.

He joined the Post Office in 1916 and since 1922 has been in the wireless telegraph section. During the war he was for some time in charge of coastal radio stations and interception stations. For two years (1946 to 1948) Mr. Murdoch was seconded to the radio section of the Control Commission in Germany.

OUR AUTHORS

J. G. Thomason, author of the article describing a photographic timer, worked on communications circuit research during the war and returned to Liverpool University in 1946 to complete a science degree. He subsequently joined the Atomic Energy Research Establishment from which he transferred to the Radar Research Establishment in 1954. He is the author of a recent book on negative feedback theory ("Linear Feedback Analysis," Pergamon Press).

R. J. D. Reeves, contributor of the article "Voltage Coincidence Oscillograph" in this issue, is a project engineer with E. K. Cole Limited, which he joined in 1949. He was formerly a control room engineer with the B.B.C. Among the development projects undertaken by our contributor, who is at present investigating stroboscopic methods in oscillography, are linear amplifiers, radar ranging systems and klystron control systems.

J. Kason, who surveys sound and television distribution systems on page 88, is senior engineer-in-charge of the television relay laboratory of E.M.I.'s domestic electronics division, where he is responsible for the design and development of television relay equipment. He received the National Diploma in electrical engineering at the Polytechnic, London, where he afterwards did post-graduate research in electro-acoustics.

R. G. Wicker, author of the article on "wow" and "flutter" measurement, spent four years in the R.A.F. as a fitter of airborne radar before joining the G.E.C. in 1948, where he is now engaged mainly on the development of signal generators and signal sources for use within the company. He is a part-time teacher of radio and mathematics at the Birmingham College of Technology and is a founder member of the Coventry group of the International Radio Control Model Society.

OBITUARY

Frederick J. Toone, O.B.E., managing director of Parmeko Limited, died on December 17th at the age of 47. He joined the company in 1930 and was appointed an O.B.E. in 1948 for his services to the industry.

IN BRIEF

Of the 14,217,323 **Broadcast Receiving Licences** in force in the United Kingdom at the end of November, 5,261,699 were for television and 288,187 for car radio receivers. The month's increase in television licences was 183,437.

Retail Sales of television receivers in November were 72,000 (26 per cent) lower than in the record month of October, when 282,000 sets were sold. The B.R.E.M.A. survey also shows a decrease in sound receiver sales of 30 per cent (95,000 compared with 123,000) and in radiograms of 33 per cent (24,000 compared with 36,000).

New "Eurovision" Centre.—The European Broadcasting Union, which among other things is responsible for the planning and direction of international television relays, decided last year to transfer the international television co-ordination centre from Lille to Brussels. The new centre, which has been built for the E.B.U. by the Belgian National Broadcasting Corporation, was taken into service just before Christmas. Separate engineering and programme control rooms have been provided, with facilities for handling two simultaneous transmissions.

Stereophonic Reproduction of recorded music is now provided at the New Gallery, Regent Street, which has recently been set up as a religious and cultural centre. E.M.I. Stereosonic tape records are reproduced at lunch-time concerts each week-day and on Tuesday evenings.

Antipodean Television.—According to a statement by the Australian Minister of National Development, six of the twelve companies preparing to make television sets in the Commonwealth are associated with American manufacturers, three with British, two with organizations in both these countries and one with a Dutch parent company. Marconi's announce that, in addition to providing all the transmitting and aerial equipment for the first two Government television stations in the Commonwealth, they have received orders through their Australian associates—Amalgamated Wireless (Australasia)—for equipment for two commercial télevision stations at Sydney and Melbourne.

Low-power Equipment.—The first of the Practical Reference Sheets which are being issued by the QRP Society describe the low-power transmitter and receiver which, as mentioned last month, took first prize in the Society's contest for portable equipment.

"QST," the official journal of the American Radio Relay League, celebrated its 40th anniversary in December. When it was launched in 1915 the A.R.R.L. was barely eighteen months old and its membership, which to-day is 50,000, was about 600. The anniversary issue includes a copy of the first number.

In preparation for the start of transmissions from the I.T.A. Lancashire station a **Television Aerial Convention** is being organized in Manchester by Belling & Lee. A talk will be given by G. L. Stephens, chief engineer of the company, and this will be followed by a discussion on Band III aerials. Technically interested readers may apply to Belling & Lee, at Enfield, for tickets for the convention which will be held at 2.15 on February 22nd at Belle Vue, Manchester.

Lectures on **Band III Aerials** are also being arranged by Antiference. Three are announced for February: 1st (3.30) at Midland Hotel, Manchester; 2nd (4.0), Adelphi Hotel, Liverpool, and 23rd (3.30), Bull and Royal Hotel, Preston.

Electronics and Productivity is the title given to an exhibition and conference to be held in the Kelvin Hall, Glasgow, from February 6th to 9th. Over fifty firms are exhibiting and a number of research organizations are participating.

Silicones.—A public exhibition covering the history, production and industrial applications of silicones is to be held at the Tea Centre, Lower Regent Street, London, S.W.1, from February 7th to 18th. Entitled "Silicones for industry," it is being staged by Midland Silicones, Limited, and will be open each week-day from 10 a.m. until 6 p.m.

Instrument Centre.—Having taken over the whole of the building at 20, Queen Anne Street, London, W.1, the Scientific Instrument Manufacturers' Association is devoting an entire floor to setting up a permanent exhibition. Space will be allocated by ballot to members of the Association for limited periods so that the exhibits will constantly change. It opens on February 9th.

BUSINESS NOTES

B & K Laboratories, Limited, of 59/61, Union Street, London, S.E.1, associates of Rocke International, Ltd., of the same address, announce that, in addition to handling a considerable number of foreign measuring instruments, they are now stocking equipment manufactured by a number of British manufacturers. With the expansion of the company's activities, C. J. Mitchell, formerly of Racal, Limited, has been appointed chief engineer.

Seismic Instruments, Limited, has been formed jointly by Pye, Limited, of Cambridge, and Electro-Technical Labs. Inc., of Houston, Texas, for the manufacture in this country of American instruments for use in prospecting for oil and other minerals. Production of the instruments, some of which are electronic, will be undertaken at the works of W.G. Pye & Company.

The **General Electric Research Laboratory,** of Schenectady, has appointed Dr. George J. Szasz as its first scientific representative abroad and he will occupy an office in Crown House, Aldwych, London, W.C.2.

New facilities for research on the materials and processes used in the manufacture of cathode-ray tubes have been provided by the **General Electric Company** at the Research Laboratories, Wembley.

Arrangements have been made by **Jones & Stevens, Limited,** of Long Lane, Littlemore, Oxford, to manufacture fractional horse-power motors of continental design. Weighing 8ozs, and measuring approximately 3in by 2in, the motors have an output of 1/70th h.p.

The main vision and sound transmitters, monitoring equipment and aerial system for the permanent television station on Pontop Pike, Co. Durham, recently brought into service by the B.B.C., were supplied by **Marconi's.** The 5-kW vision transmitter has an e.r.p. of 12 kW.

The total number of ships of all classes for which **Decca Radar** has been ordered now exceeds 4,500, operated by more than 1,000 shipowners and authorities throughout the world. One of the latest ships to be equipped with the Type 45 is the new *Empress of Britain*. The latest order for the Decca 212 (introduced last February for smaller craft) is for two vessels operating a ferry service across the Tyne between North and South Shields.

Orders for **Cossor's** 10-cm airfield control radar, Mark VI, now exceed £1M. Five are already at work including three overseas.

To mark the silver jubilee of the establishment of the Chalk Farm factory of **Ultra Electric,** the employees made a presentation to their managing director, E. E. Rosen.

NEW ADDRESSES

The head office of the **Telegraph Construction and Maintenance Company** and its associate company, Submarine Cables Limited, has been transferred from Old Broad Street, London, E.C.2, to Mercury House, Theobalds Road, W.C.1 (Tel.: Holborn 8711). The London sales offices of Telcon (previously in Norfolk House, St. James's Square) and the recently acquired Magnetic and Electrical Alloys (previously in Baker Street) are also in Mercury House.

Cable and Wireless are now installed in their new offices at Mercury House, 110-124, Theobalds Road, London, W.C.1 (Tel.: Chancery 4433).

A. M. Lock and Company, northern agents for a number of manufacturers of electronic and nucleonic equipment, have opened offices at 79, Union Street, Oldham, for their sales and accounts division. The works and service department now occupy the whole of the premises in Crompton Street, Chadderton, and arrangements are being made for a sales and service department in Birmingham.

The telegraphic address of **Winston Electronics, Ltd.,** of Shepperton, Middlesex, has changed from "Control, Shepperton," to "Winston Shepperton."

Land, Speight and Company and its associates Elesco Electronics Limited, have moved from Robertson Street, Glasgow, C.2, to 2 Fitzroy Place, Sauchiehall Street, Glasgow, C.3. The telephone number is unchanged: Central 1082.

The headquarters of the **Electrical Industries Benevolent Association** are now at 10, Buckingham Palace Gardens, London, S.W.1. (Tel.: Sloane 9811.)

OVERSEAS TRADE

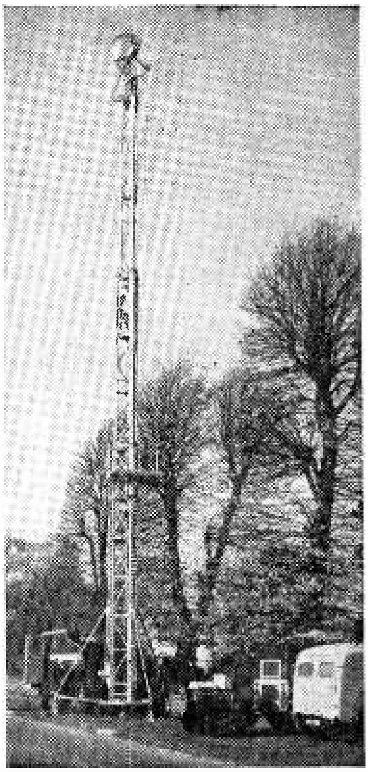
Radio Exports set up a new record in November when, according to figures issued by the Radio Industry Council, over £3.1M worth of equipment was sold overseas. This was £100,000 more than the previous highest figure reached in October. The value of broadcast receivers exported during November (£456,000) was the highest monthly figure since January 1952.

Cyprus.—Equipment for a comprehensive radio-telephone network for the police on the island has been provided by A.T. & E. (Bridgnorth) Limited. The installation includes 10-watt single-channel transmitters at fifty police stations and a number of 50-watt a.m. headquarters stations. Patrol cars are also being equipped.

Ecuador.—A million dollar order for a multi-channel radio telephone/telegraph system linking a number of the more important cities and towns in Ecuador has been placed with Marconi's. The system, which will provide carrier-telephone, voice-frequency telegraph and teleprinter services, will form the backbone of a communications network which will eventually cover the entire country. The carrier-telephone equipment is being provided by the Automatic Telephone and Electric Company and the voice-frequency telegraph equipment by the Telephone Manufacturing Company.

Sweden.—Svenska Radiobyran, Kungsgatan 10, Gothenburg, wish to get in touch with U.K. manufacturers of television receivers with a view to securing an agency for the whole of Sweden or, if that is not possible, for the middle and western areas. Sweden has adopted the 625-line system and a service is planned to begin this summer.

Belgium.—The third International Technical and Industrial Exhibition, to be held at Charleroi from September 15th to 30th, will again include a section devoted to electro-technical engineering and electronics. Last year the United Kingdom provided the second largest overseas contingent at the exhibition.



NEW mobile extending tower, introduced by the B.B.C. for radio links in television outside broadcasts, enables the transmitting or receiving paraboloid to be raised to a height of 60ft. The aerial can be rotated continuously through 360° in azimuth, and a remote control system is used to align it on the distant end of the radio link with an accuracy of within ½°. When in transit the tower is carried in a horizontal position on the vehicle and is raised by a system of hydraulic rams.

Two-Metre Transmitter-

Companion V.H.F. Unit for Use with Portable Equipment Described Earlier

IN an earlier article[1], the writer described a transmitter-receiver for the 160- and 80-metre amateur bands, designed mainly for portable operation, but equally suitable for use as a low-power home station. Since then, the modification to the amateur licence permitting operation from any location in the United Kingdom has encouraged portable and " alternate address " working, and further impetus has been given to the construction of compact apparatus by the Radio Amateur Emergency Network. The 7-, 14-, 21- and 28-Mc/s amateur bands did not offer much encouragement to very low power working, but the next higher frequency band, from 144 to 146 Mc/s, appeared to be worth tackling. The resulting transmitter-receiver unit is described in this article, and although it has been designed for use in conjunction with the receiver-control unit previously described, the transmitter is complete in itself, while the receiver part, in fact a convertor, may be used with any receiver that can be tuned to 3.6 Mc/s or thereabouts. Alternatively, by modifying the tuning range of the oscillator, and of the i.f. amplifier stage of the convertor, it could be used with almost any short-wave receiver.

The transmitter input is of the order of 6 watts, which, in conjunction with the high-gain aerial arrays possible on the higher frequencies, is capable of making itself heard at considerable distances. The complete transmitter-convertor is built in one box, measuring 8in × 4in × 5in deep, that is, identical to each of the earlier units, and as before, one type of valve is used wherever possible, thus simplifying the spares problem. The 6AM6 used in the lower frequency equipment is not ideally suited to

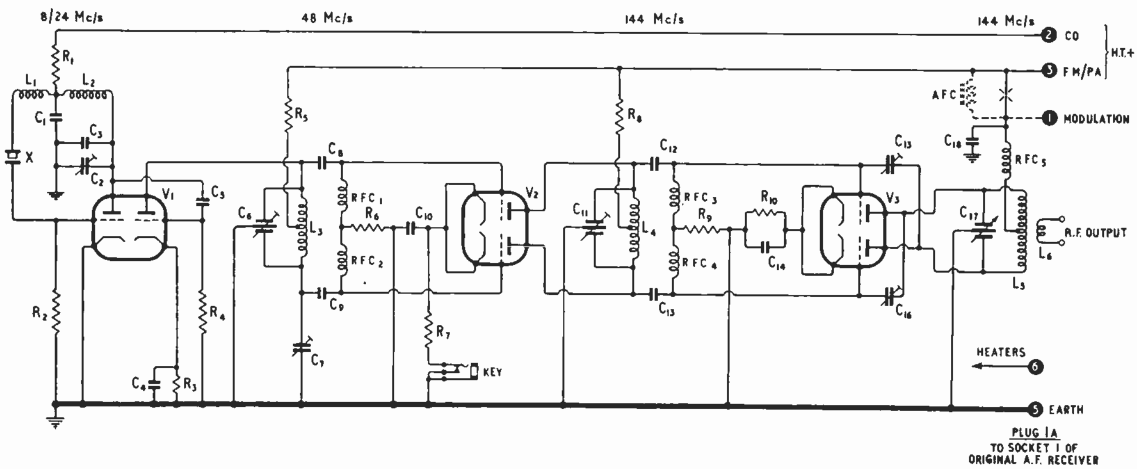


Fig. 1. Circuit diagram of the transmitter section. The dotted part indicates the modification to permit telephony operation.

LIST OF PARTS: TRANSMITTER.

Capacitors

C_1	680 pF silver mica
C_2	50 pF trimmer (Eddystone 553)
C_3	22 pF s.m.
$C_{4, 10}$	1000 pF ceramic (TCC CTH 310)
$C_{5, 8, 9}$	47 pF s.m.
$C_{6, 11}$	25 × 25 pF butterfly trimmer (Eddystone 551)
$C_{7, (19)}$	30 pF trimmer (Oxley " Minitrimmer ")
$C_{14, 18}$	100 pF s.m.
$C_{12, 13}$	4.7 pF ceramic
$C_{15, 16}$	8 pF trimmer (Philips concentric)
C_{17}	34 × 34 pF butterfly variable (Eddystone 584)

Resistors:

$R_{1, 5, 8}$	1.5 kΩ	1 watt	R_4	56 kΩ	½ watt
$R_{2, 9}$	1 kΩ	½ ,,	R_6	5.6 kΩ	½ ,,
R_3	220 Ω	¼ ,,	$R_{7, 10}$	100 Ω	¼ ,,

Coils:

L_1	4 turns, No. 18 En., ½in diam., close wound
L_2	10 turns, No. 18 En., ½in diam., close wound
L_3	16 turns, No. 18 En., ½in diam., centre tapped, 1⅛in long
L_{3A}	8 turns, No. 18 En., ½in diam., centre tapped, 1in long
L_4	5 turns, No. 18 En., ½in diam., centre tapped, 1in long
L_5	3 turns, No. 16 En., ½in diam., centre tapped, ¾in long
L_6	1½ turns, No. 16 En., in centre of L5.

Sundries:

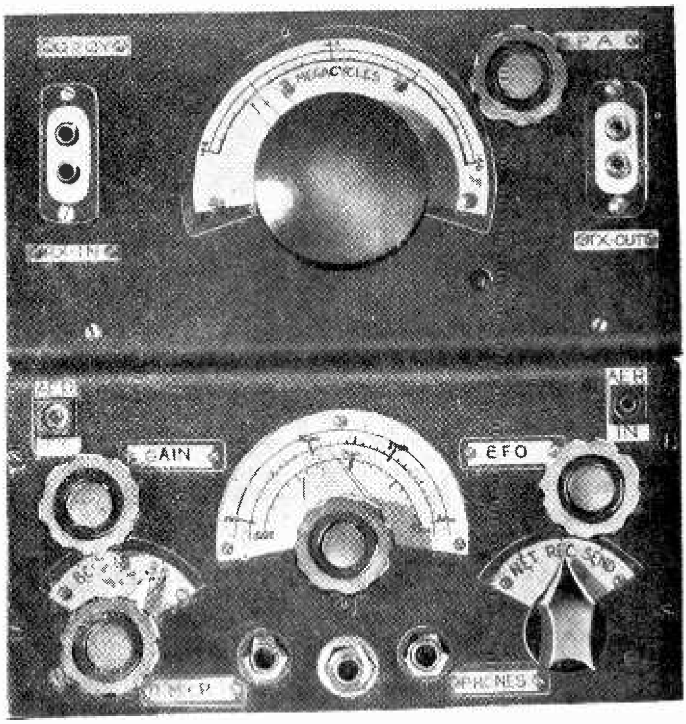
$RFC_{1, 2}$	3.5 μH (60 turns, No. 30 En., $\frac{3}{16}$in diam, close wound on former 1⅛in long)
$RFC_{3, 4, 5}$	1.6 μH (30 turns, as above, but former ⅝in long)
$V_{1, 2, 3}$	12AT7 (ECC81)
X	Crystal (operating frequency ÷18) (see text)
AFC	20H, 30 mA.

Convertor

By G. P. ANDERSON*

145 Mc/s, and the 12AT7 is therefore adopted for all the higher frequency positions in the transmitter and convertor, and a 6AM6 for the intermediate frequency amplifier at 3.6 Mc/s. Provision is made for monitoring the transmissions in a similar manner to that used in the low-frequency apparatus, and whilst primarily intended for morse (or " c.w.") operation, the transmitter may be used for telephony.

Transmitter: The three-valve crystal-controlled transmitter, the circuit of which is shown in Fig. 1, utilizes a regenerative oscillator circuit, whereby a crystal of nominal frequency in the 8-Mc/s region is made to oscillate on its third overtone, i.e., approximately three times its fundamental frequency. This function is performed by one-half of the first 12AT7, the second triode being used as a frequency doubler, to 48 Mc/s; the second 12AT7 is run as a push-pull frequency tripler, the output at 144 Mc/s being amplified by the last valve, operating as a push-pull neutralized amplifier.



Complete 145 Mc/s transmitter-receiver. The upper unit comprises the transmitter-convertor described in this issue; the lower unit consists of the receiver-control unit described in an earlier issue (see text).

The external field at 48 Mc/s is very low, and should not cause any interference with television reception. In some parts of the country, and especially in fringe areas, where trouble may be feared, a simple modification to the second stage will enable it to be used as a push-pull frequency doubler, the second part of V_1 then being tuned as a frequency tripler to 72 Mc/s. The modifications to the circuit are shown in Fig. 2, and an additional trimmer (C_{19}) will be required. It is this slight extra complication that prompted the writer to decide on 24–48–144 Mc/s as the frequency train.

All interstage couplings are capacitive, simplifying adjustment of the transmitter; the value of 4.7 pF for C_{12} and C_{13} may seem rather low, but any increase results in a severe drop in drive to V_3. The purpose of C_7 may not be immediately apparent, but it balances the anode-earth capacitance across L_3 of the second triode of V_1, thus equalizing the drive to the two sides of V_2 and its correct adjustment gives appreciably greater output. C_{19} in Fig. 2 serves a similar purpose for L_4. Neutralization of V_3 is carried out by means of C_{15} and C_{16}, and is described in a later paragraph; the stability of this stage is assisted by the form of construction, coupling between L_4 and L_5 being minimized by placing L_4 below the chassis and L_5 above it, as may be seen in the photographs. The early stages are pretuned, and the only control that requires adjustment during operation, and then only when setting up the station or changing aerials, is the tuning of V_3 anode circuit, and this is brought out as a panel control.

The layout is relatively unimportant, provided lead lengths are kept to a minimum, and the positions of the components shown enables this to be achieved together with easy access for wiring and adjustment. In the interests of freedom from frequency drift, care should be taken to insulate the crystal from heat as far as possible, and it will be seen that a small asbestos screen has been fitted between V_6 and the crystal (X in the top view of the transmitter) for this purpose. A slight rearrangement of the layout to increase the distance between these items would be of help. The tuned circuit L_1 L_2 C_2 is extremely sensitive to the proximity of external earthed objects, and a small shield is fitted under the chassis to reduce the effect of placing the unit on metal surfaces. The

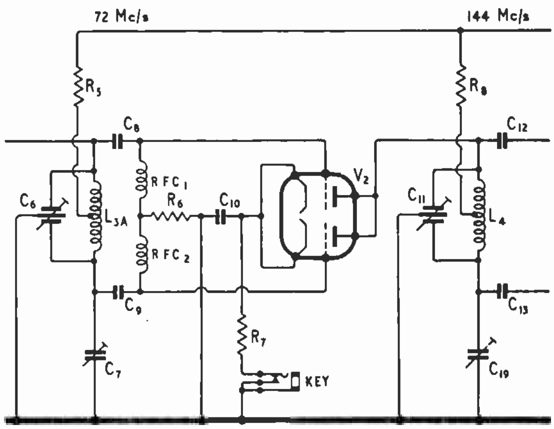
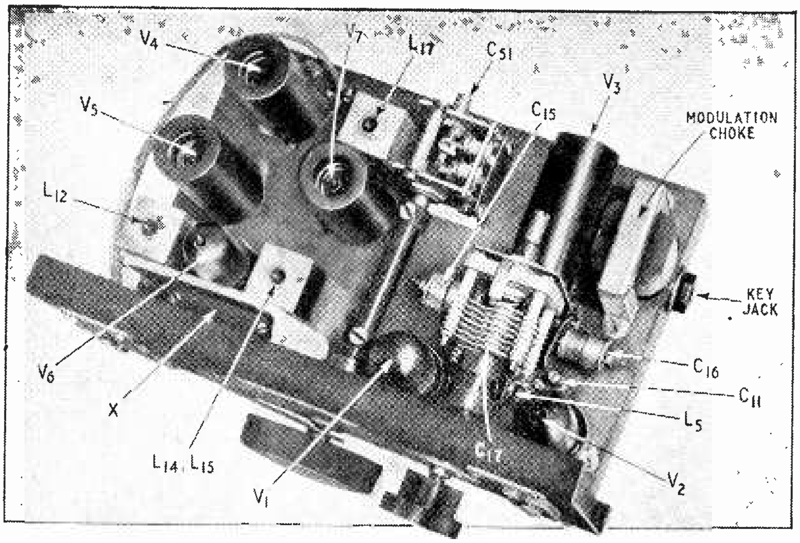


Fig. 2. Modification to the circuit associated with V_2, to avoid a 48-Mc/s signal, and possible interference with television in certain areas.

* Amateur radio station G2QY.



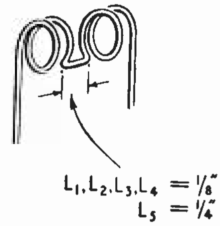


Fig 3. Details of the coils in the transmitter, showing the method of centre-tapping.

Top view of v.h.f. unit, showing layout of the components.

coils are all self-supporting, and the method of tapping found most convenient is shown in Fig. 3. Inductors L_1 and L_2 may be wound in one operation, the junction being tapped as suggested, and the degree of coupling adjusted by changing the angular position of L_1 relative to L_2.

Several ex-Service crystals in the 8-Mc/s region have been tried in this transmitter, and satisfactory control on the third overtone has been obtained in each case, although with varying degrees of ease of adjustment. Thus, although a " surplus " crystal of suitable frequency may be used, it would be beneficial to obtain one specifically designed for overtone operation. Operation on the overtone of a standard crystal will not produce the exact multiple of its fundamental frequency, but the difference will be of the order of a few kilocycles only at 145 Mc/s.

The adjustment of the transmitter is quite straightforward, but will be greatly simplified by the use of a grid-dip oscillator such as the one recently described in this journal[2], using such an instrument it is possible to set up the transmitter almost completely before applying the h.t. voltage It is suggested that the circuits L_3C_6, L_4C_{11} and L_5C_{17} should be tuned to their appropriate frequencies as shown in Fig. 1, by means of the g.d.o., with all valves in place but with no h.t. applied to the transmitter; heater voltages may also be disconnected. Supplies should then be connected to the first triode of V_1, h.t. current to the oscillator being measured by a milliammeter in series with R_1. With a crystal of suitable frequency in position, C_2 may be varied, when changes in the anode current should be apparent, the current being lowest when the valve is oscillating. The coupling between L_1 and L_2 should be reduced, by bending L_1 away from L_2, until a dip in the anode current occurs at only one point during the rotation of C_2. In the prototype this is achieved when L_1 lies almost at right angles to L_2. The object of this adjustment is to permit sufficient feedback to sustain oscillation to occur only through the resonance of the crystal; if there is too much coupling between L_1 and L_2 feedback will take place through the parallel capacitance of the crystal, its holder and associated wiring, under which conditions the valve will oscillate at a frequency independent of the crystal. A final check of the stability of the oscillator may now be made by listening to it on a receiver in the 24-Mc/s range, or if more convenient, to a harmonic thereof.

Power may now be applied to the second half of V_1, and to V_2, and L_3C_6 and L_4C_{11} tuned, with C_7 set at approximately mid capacity. A small low-wattage cycle-lamp bulb connected across a couple of turns of wire serves as a useful indicator when loosely inserted into each of the coils in turn, but care should be taken to avoid lamps with coiled-coil form of construction, as the inductance appears to prevent sufficient current flowing (with the low powers concerned here) to produce a light. An alternative and more sensitive, detector consists of the grid-dip oscillator, which, when coupled to a tuned circuit carrying r.f. power, will show an increase in grid current when tuned to the same frequency. The indication, it should be mentioned, is very sharply tuned, compared with the dip associated with the usual application of the g.d.o. In making the initial tune-up, however, the more usual method of tuning for maximum grid current in the following stage may be found advantageous.

Having adjusted the circuits associated with V_2, so that a signal at 144 Mc/s is being applied to the grids of V_3, the latter stage should be neutralized, and any of the popular methods may be used. The writer found the simplest to consist of coupling the small lamp into L_4 just sufficiently to obtain illumination, then setting C_{15} and C_{16} to a minimum, and varying C_{17}. This produces a dimming of the lamp at resonance, but by slowly increasing C_{15} and C_{16} by equal amounts, and checking by rotating C_{17}, a point will be reached where no effect is visible on the lamp when C_{17} is rotated. The neutralizing capacitances needed are about 4 pF. It may be advisable to retune C_{11} for maximum power in the lamp occasionally during this process.

H.T. may now be connected to the last stage, and L_5C_{17} tuned. Sufficient power should now be available across L_6 to light a 6V 0.3A torch bulb, and retuning all stages in turn may now be easily carried out. At this stage, too, it is convenient to finally set C_7, and this may be done by trying various settings of C_7, and retuning C_6, until maximum

TABLE 1

H.T. current drawn by various stages, and under various conditions.

Stage	mA
V_{1a} (CO/FT)	15
V_{1b} (FD)	8
V_2 (FT)	20
V_3 (PA) (12AT7)	28 (loaded by aerial)
V_3 (PA) (12AU7)	32 (loaded by aerial)

Note : These currents are measured in the h.t.+feed to each valve; cathode currents are higher due to the presence of grid current under driven conditions.

Transmitter total, including modulator:

12AT7 in V_3 : 81 mA.

12AU7 in V_3 : 85 mA.

Convertor: 34 mA.

Convertor and receiver: 60 mA. (72 mA. with output stage in use).

The above were measured with 250 volts h.t.

power output is achieved; the setting is fairly critical. A similar adjustment must be made to C_{19} if the circuit of Fig. 2 is used.

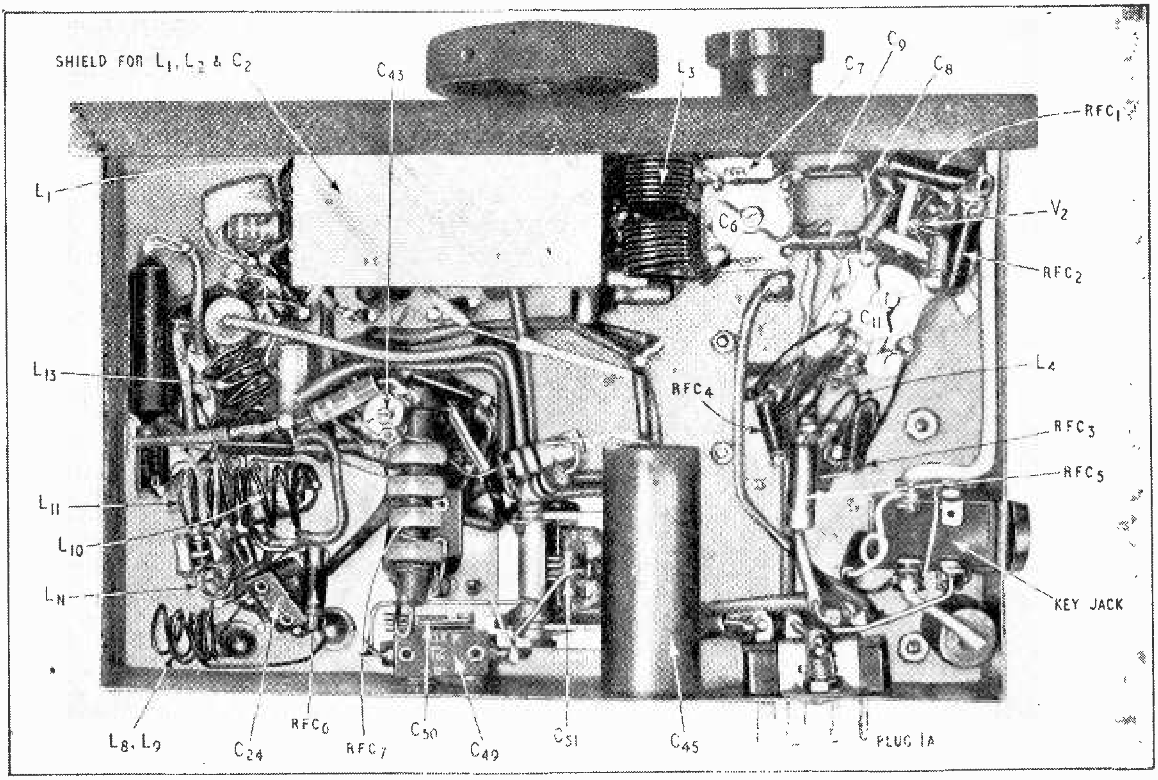
A significant increase in output may be obtained at the cost of greater h.t. consumption, by substituting a 12AU7 (ECC82) for V_3. The only alterations necessary, apart from retuning C_{11} and C_{17}, will be a slight reduction in the values of C_{15} and C_{16}, due to the lower inter-electrode capacitances of the 12AU7.

The currents drawn by the various stages on a 250 volt h.t. supply are shown in Table 1.

Keying of the transmitter is carried out in the cathode circuit of V_2, the key thus being at earth potential, and although the signal is quite " clean " with the filtering provided by R_7 and C_{10}, an a.f. choke of about 5H. inductance may be substituted for R_7, and an additional 0.25-μF capacitor fitted across the key jack to completely remove all trace of key clicks. It may be necessary to mount these components on the key itself owing to space limitations inside the transmitter. Modulation of the unit may be achieved by the usual methods, and by a modification to the wiring it can be taken from the original receiver-control unit. The h.t. lead from the top of RFC_5 should be disconnected, and taken to tag 1 on the plug, and a 20-H 30-m/A choke connected between tags 1 and 3, as shown dotted in Fig. 1. Reference to the circuit diagrams accompanying the earlier article[1] will show that this produces plate modulation of the power amplifier stage in the same manner as the screens of the low frequency p.a. were modulated. The difficulty is to find a physically small enough choke to fit into the miniature apparatus, and if telephony operation is desired, a slight increase in chassis size may be necessary.

The Convertor: Three 12AT7 valves are used in the r.f. amplifier, local oscillator and mixer stages, and one 6AM6 as an i.f. pre-amplifier. The latter serves to isolate the frequency changer from the effect of any variations in the load connected to the convertor, in the form of the accompanying main receiver; it provides also some useful gain. The circuit is shown in Fig. 4.

The first stage comprises the two triodes of one



View underneath the v.h.f. unit, showing the positions of the principal components.

12AT7 connected as an earthed-cathode earthed-grid, or cascode, amplifier, the neutralization of the earthed-cathode section being achieved by C_{24} L_N, which is non critical, but trial adjustments may be made to L_N, by varying the spacing between the turns, in order to improve the signal-to-noise ratio under working conditions. The mixer stage, V_5, uses one half of a 12AT7 with the grid circuit self resonant (i.e. the inductance of L_{11} is tuned by the input capacitance of V_5 to 145 Mc/s), and the oscillator voltage is injected into the grid in parallel with the signal, through C_{40}. The mixer is operated with low h.t. voltage, as this was found to give the best signal-noise ratio in this stage. The plate circuit is tuned to the intermediate frequency, in this case 3.6 Mc/s, by adjusting the core of L_{12} against the fixed C_{30}; the other half of V_5 is used as the monitor, and will be dealt with later.

The following i.f. amplifier, V_6, is quite standard.

The local oscillator is perhaps novel in its use of the series-tuned colpitts, or " Clapp," oscillator, which is often found in transmitter circuits, and which is used here at a much higher frequency than is customary. One half of V_7 is operated as the oscillator, the circuit constants being selected to enable it to tune over the range 28·08 to 28·48 Mc/s, while the other triode is a frequency quintupler, with its output at 140.4 to 142·4 Mc/s. This oscillator has proved to be extremely stable over long periods, and the output from the multiplier, damped as it is by using a fairly high value for C_{40}, is sufficiently constant to produce efficient conversion over the 144- to 146-Mc/s range.

The frequency of the oscillator was chosen in the 28-Mc/s amateur band to simplify the setting up and calibration procedure, since most amateurs have

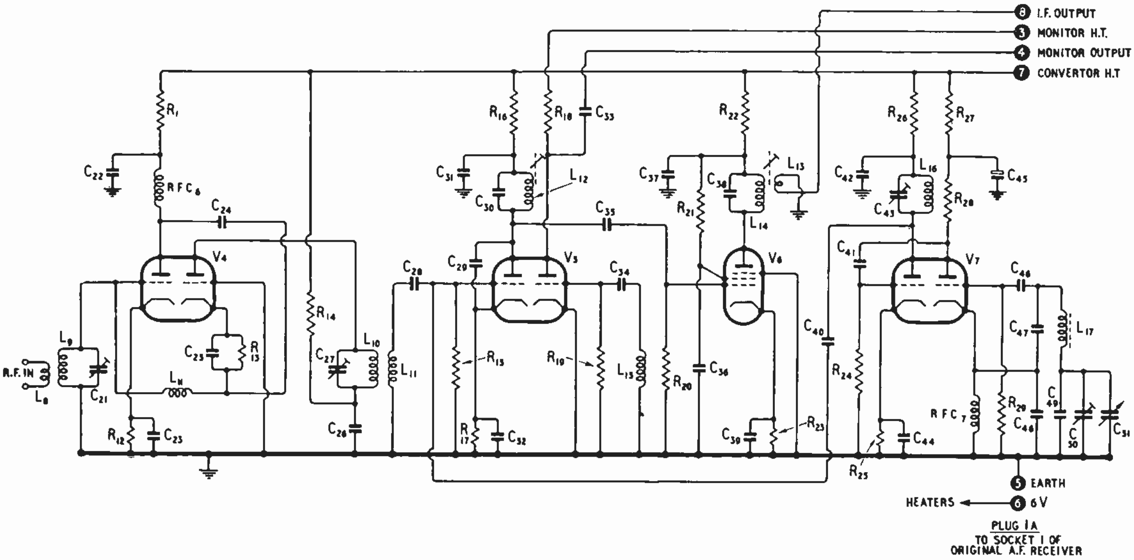


Fig. 4. Circuit diagram of the convertor section. The right-hand half of V_5 is used as a monitor during transmission. The local oscillator is at the extreme right, the left-hand triode of V_7 being the frequency quintupler.

LIST OF PARTS: CONVERTOR

Capacitors:

C_{21}	8 pF trimmer (Philips concentric)
$C_{22, 23, 25, 26, 31, 32, 36, 37, 39, 42, 44}$	1000 pF ceramic (TCC CTH 310)
$C_{24, 35, 46}$	47 pF silver mica
$C_{27, 43}$	10 pF trimmer (Oxley " Minitrimmer ")
$C_{28, 34, 41}$	100 pF s.m.
$C_{29, 40}$	10 pF ceramic
$C_{30, 38}$	133 pF (100 + 33 pF s.m.)
C_{33}	0.1 μF 250V wkg.
C_{45}	8 μF electrolytic, 250V wkg.
$C_{47, 48}$	220 pF s.m.
C_{49}	150 pF s.m.
C_{50}	50 pF trimmer (Eddystone or Oxley)
C_{51}	25 pF variable.

Resistors:

$R_{11, 14, 27}$	1 kΩ	½ watt	R_{18}	56 kΩ	½ watt
$R_{12, 13}$	470 Ω	¼ ,,	R_{20}	470 kΩ	¼ ,,
$R_{15, 19}$	1 MΩ	¼ ,,	R_{21}	100 kΩ	½ ,,
R_{16}	470 kΩ	½ ,,	$R_{22, 26, 28}$	5.6 kΩ	½ ,,
R_{17}	100 Ω	¼ ,,	$R_{23, 25}$	220 Ω	¼ ,,
			$R_{24, 29}$	22 kΩ	¼ ,,

Coils:

L_8	3 turns, No. 18 En., ½in diam., interwound with L_9
$L_{9, 10}$	3 turns, No. 18 En., ½in diam., ½in long
$L_{11, 13}$	4 turns, No. 18 En., ½in diam., ⅝in long. (L_{11} mounted very close to L_{10})
$L_{12, 14}$	55 turns, No. 32 En., (See note below)
L_{15}	10 turns, No. 32 En., wound on earthy end of L_{14}
L_{16}	4 turns, No. 18 En., ½in diam., ½in long
L_{17}	8 turns, No. 16 En., ½in long, wound on former (see note below), and Distrene varnished.
L_N	5 turns, No. 22 En., ¼in. diam.

(Note: L_{12}, L_{14}, L_{15} and L_{17} are wound on 0.3in former—Neosid coil former Type 5000/6E, iron dust core Drg 500, top plate Drg 5001, and John Dale screening can DTV2).

Sundries:

RFC_6	as $RFC_{3, 4, 5}$
RFC_7	1.25 mH Choke (Eddystone 1010)
$V_{4, 5, 7}$	12AT7 (ECC81)
V_6	6AM6 (EF91)

access to a receiver covering this band. Having obtained oscillations in the band, by adjustments to L_{17} and C_{50}, C_{51} should be set to maximum value, and C_{50} adjusted so that the oscillator is on 28.08 Mc/s. The frequency obtained with C_{51} set to its minimum should now be found, and if it is higher than the desired 28.48 Mc/s, the core of L_{17} should be withdrawn a turn or so, C_{51} reset to its maximum and the oscillator retuned to 28.08 Mc/s by increasing C_{50}. A further check should now be made of the range covered by C_{51}, and further adjustments made to L_{17} and C_{50} until slightly more than the desired frequency range is covered. (It is of course apparent that if less than 400 kc/s is covered by C_{51}, the reverse of the above procedure should be followed.)

The grid-dip oscillator is particularly useful in adjusting the tuned circuits in the convertor to their correct frequencies, and this should be done with each stage in turn, with no h.t. on the receiver, but with the valves inserted. If it is found that any circuit will not tune to its appropriate frequency (i.e. 145 Mc/s for L_9, L_{10} and L_{11}, and 141.4 Mc/s for L_{16}) the coils should be adjusted, remembering that squeezing the turns together will increase the inductance and hence lower the frequency, and *vice versa.* Final tuning should be carried out on a 145-Mc/s signal, which may conveniently be that of the g.d.o. placed near the receiver. All the signal frequency circuits, apart from the input, are pre-tuned at the centre of the band, the small trimmers being fitted under the chassis.

Some tendency to instability at the signal frequency was observed in the mixer stage, but the addition of the 10-pF condenser, C_{29}, directly across anode and cathode of this stage completely cured the trouble.

In order to take full advantage of the facilities provided on the original receiver-control unit, a slight modification to the latter is necessary. Referring to the circuit shown in Fig. 2, page 595 of the December 1953 issue of *Wireless World*, an additional connection should be made from the h.t. line to the r.f. stages, i.e. the top end of R_5, to pin 7 of the socket 1. This enables the h.t. to the convertor to be controlled by the net-receive-send switch. It will also be seen that with the switch in the net position, h.t. is applied to the crystal oscillator stage of the transmitter, *via* pin 2 of the plug; this provides a useful check on the operation of the crystal oscillator, and also of the calibration of the convertor.

A screened lead should be run also between the aerial socket and tag 8 of socket 1 on the original receiver, to provide for the connection of the convertor output to the receiver.

The monitoring facility referred to earlier is provided by the second half of V_5, which is connected as a non-oscillating leaky-grid detector, h.t. being applied when the apparatus is in the "transmit" condition. The grid circuit is tuned by the valve capacitance across L_{13}, which may be resonated to 145 Mc/s with the aid of the grid-dip oscillator. There is sufficient stray field present for no other connection to be necessary to obtain a good signal for monitoring c.w. keying and telephony, and the audio output is taken *via* C_{33} and tag 4 on the inter-unit connections to the send-receive switching on the control unit, and hence to the headphones during transmission.

Construction: The complete transmitter-convertor is built on a chassis measuring 7½in × 4⅞in × 1¼in deep. In view of the frequencies concerned, this should be copper, and of a fairly heavy gauge in order to assist in the dissipation of the considerable amount of heat developed in the seven valves. The layout can be seen from the photographs, and V_3 is mounted horizontally on a small sub-chassis, details of which are shown in Fig. 5. The neutralizing condensers C_{15} and C_{16} are mounted on the wings, the concentric trimmers lending themselves to this form of construction very well. The complete amplifier stage may be made up on this sub-chassis and then fitted to the main chassis as a unit, suitable holes having been drilled therein to pass the heater, h.t. and grid-drive connections. The front panel of the unit, measuring 8in × 4in., may be made of tin plate, the top and bottom edges being folded over for half an inch to provide stiffening and a means of securing the box that may be made to complete the unit. However, owing to the heat generated, the writer is in favour of obtaining the maximum amount of ventilation, and has constructed a skeleton box, consisting of the ribs only, in order to protect the components mechanically, leaving the space above the chassis open to the air.

Aerial connections to both receiver input and transmitter output are brought out to sockets on the Distrene blocks on the front panel, L_6 being mounted directly on its block, and arranged to lie between the two halves of L_5. No aerial change-over switching has been incorporated, as, using such low power, no losses can be countenanced. Thus in operation, to change from receive to transmit, in addition to moving the control switch to the appropriate position, it is necessary to transfer the aerial leads from one pair of sockets to the other.

The tag numbers for the power connections shown in Figs. 1 and 4 apply when this apparatus is used with the receiver-control unit of the earlier article, but no difficulty should be encountered in re-arranging the connections to suit local conditions.

Operation: Using such low power in compact apparatus, one of the chief difficulties is tuning the final amplifier anode circuit when the transmitter is

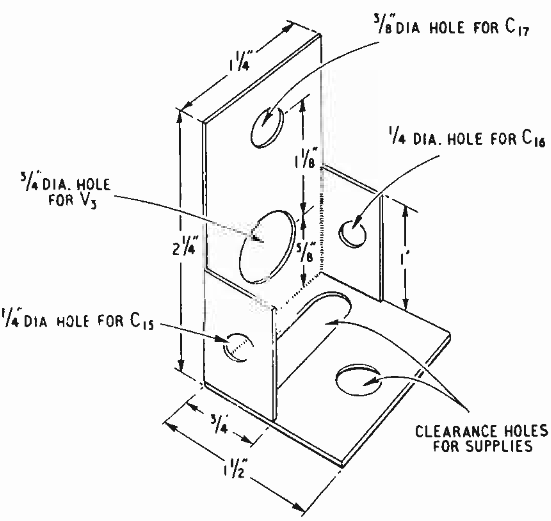


Fig. 5. Details of the sub-chassis for the amplifier stage, V_3. C_{15} and C_{16} mounted on insulating material.

connected to an aerial. It is of course possible to tune for minimum plate current, by inserting a milliammeter in series with RFC_5, or a second method uses a simple crystal diode detector and meter placed sufficiently near to the feeder line to obtain a reading, and tuning C_{17} for maximum indication. However, the writer has found a device known as the "twin lamp"[3] to be very satisfactory, as well as being simple to use during portable operation. In addition to providing an output tuning indication, this also gives a check on the standing-wave ratio on the transmission line, and hence of the aerial matching.

A good backlash-free, slow-motion drive is desirable for tuning the convertor, but a useful degree of fine tuning for weak signals is provided by the tuning control on the main receiver.

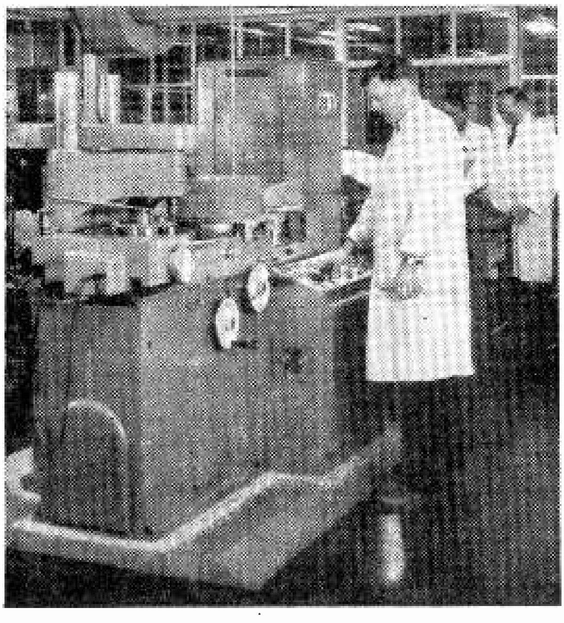
It is not proposed to conclude with a list of results, as the range of any apparatus on v.h.f. is extremely sensitive to local screening, and to propagation conditions. Suffice it to record that using an inferior indoor aerial, the third station contacted, under poor conditions, was 60 miles away, and good reports were exchanged.

REFERENCES

[1] Anderson, G. P., " Two-Band Transmitter Receiver," *Wireless World*, Vol. 59, No. 12, Dec. 1953, p. 593.
[2] Anderson, G. P., " Compact Grid-Dip Oscillator," *Wireless World*, Vol. 60, No. 9, Sept. 1954, p. 465.
[3] *The Radio Amateur's Handbook*, published by A.R.R.L.

Automatic Machine-tool Control

AN analogue computer is the heart of a new system of control devised by E.M.I. and shown here applied to a machine for cutting precision cams. Numerical information defining "marker points" on the contour to be cut is fed in on punched tape and the computer is used to interpolate between these points. The "marker points" are actually successive radial dimensions of the outline of the cam, and the tape is fed into the machine in synchronism with the rotation of the work-table so that for each new "marker" radius the work is in the appropriate angular position. Several successive values from the tape are held temporarily in a storage system and thereby are made available simultaneously (in the form of voltages) so that they can be applied to the computer for interpolation. The computer then produces voltages representing radial dimensions of a parabolic curve between the "marker" points, and these are used to control a mechanism which moves the work-table longitudinally relative to the cutting tool.



Books Received

Electronic and Radio Engineering, by F. E. Terman, assisted by R. A. Helliwell, J. M. Pettit, D. A. Watkins and W. R. Rambo. Enlarged fourth edition of the author's "Radio Engineering" covering basic principles and techniques and containing much additional material on transistors and similar semi-conductor devices, wide-band amplifiers, pulse techniques and travelling wave tubes. Pp. 1078; Figs. 678. Price 71s 6d. McGraw-Hill Publishing Company, Ltd., 95, Farringdon Street, London, E.C.4.

Transistor Electronics, by A. W. Lo, R. O. Endres, I. Zawels, F. D. Waldhauer and C.-C. Cheng. Comprehensive treatise by R.C.A. workers on the basic circuit configurations for low- and high-frequency amplifiers, oscillators, modulators and demodulators, pulse generators and switching circuits; with emphasis on design procedure. Pp. 521; Figs. 354. Price 96s. Prentice-Hall, Inc. Agents: Bailey Bros. and Swinfen, Ltd., 46, St. Giles High Street, London, W.C.2.

The Design of a Ribbon Type Pressure-Gradient Microphone for Broadcast Transmission, by D. E. L. Shorter, B.Sc.(Eng.), A.M.I.E.E., and H. D. Harwood, B.Sc. Engineering Division Monograph No. 4 giving an account of the development of the types PGS and PGD small ribbon microphones, their electrical, mechanical and acoustical features and performance. Pp. 22; Figs. 25. Price 5s. B.B.C. Publications, 35, Marylebone High Street, London, W.1.

British Standards Institution Annual Report 1954-5. Covers all activities of the Institution and lists titles of recently issued standards and of works in hand. Membership lists of the Councils and Committees are given, including those concerned with acoustics, cinematography, electrical engineering, instrumentation and telecommunications. Pp. 243. Price 5s. British Standards Institution, 2, Park Street, London, W.1.

World Radio Handbook 1956, Edited by O. Lund Johansen. Tenth anniversary edition of the international directory of sound and television broadcasting stations, their wavelengths, interval signs, times of transmission, etc. Pp. 168 with numerous illustrations. Price 10s 6d. Agents: W. Dawson and Sons, Cannon House, Macklin Street, London, W.C.2.

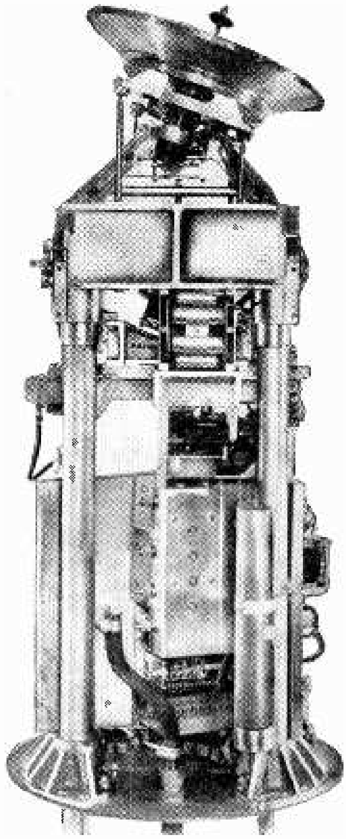
Nachrichtenübertragung Mittels Sehr Hoher Frequenzen, by Gerhard Megla. Textbook of v.h.f. and u.h.f. telecommunications techniques covering the general principles of propagation and systems design, and a description of typical aerial systems, transmitters and receivers. Pp. 272; Figs. 171. Price DM 17. Fachbuchverlag Leipzig, Karl Heine Strasse 16, Leipzig, W.31.

Glossary of Terms Relating to Automatic Digital Computers (B.S. 2641:1955). Presents the general useage among workers in this subject in the United Kingdom. Pp. 15. Price 3s. British Standards Institution, 2, Park Street, London, W.1.

Radar Guided Missiles

Principles of Control Systems Used in Ground-to-Air Defence Weapons

This article should not be taken as being necessarily representative of the latest techniques in missile guidance systems. We feel that it is worth publishing, however, in order to keep our readers abreast of the present state of knowledge on the subject.



Airborne homing equipment from a guided missile.

GUIDING a missile towards an airborne target can be considered in one sense as a navigational problem in which continuous measurements are made of the relative positions of the missile and target and the resultant information is used for automatically steering the missile. In another sense the operation can be regarded in the light of a closed-loop servo system, where the mechanism works to reduce an error-signal (distance between missile and target) to zero. However one looks at it, the business demands some method of measuring the relative positions of the missile and target in space, and, of course, one of the most powerful means of doing this is by radar.

Three main methods by which radar can be used for missile guidance were described recently to a very well attended meeting of the Radar Association by W. H. Stephens, head of the Guided Weapons Department of the Royal Aircraft Establishment at Farnborough. In the first method, known as "command guidance," there are two ground radar sets, one of which automatically tracks the target and the other the missile (see Fig. 1). The information on range, bearing and height from each set is passed to a computer, which calculates the control movements necessary to steer the missile towards the future position of the target. Signals representing these control movements are then transmitted by radio to the missile, which behaves accordingly.

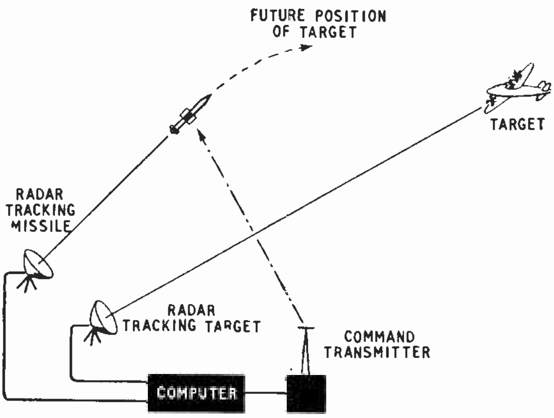


Fig. 1. Essential features of the "command guidance" system.

A great advantage of the command guidance system is that most of the electronic equipment is concentrated on the ground. Another system described by Mr. Stephens requires more apparatus in the missile but perhaps offers a greater chance of successfully intercepting the target. This is called "semi-active homing" (see Fig. 2 on next page). Here there is a single radar set on the ground tracking the target and continuously "illuminating" it with electromagnetic radiation. The energy reflected by the target is picked up by a directional parabolic aerial in the nose of the missile itself, and, according to the direction from which the radiation is coming, the aerodynamic control surfaces are moved so that the missile automatically homes on the source—that is, the target. The homing system, however, does not keep the missile continuously pointing at the target during its flight. If it did, such a violent slew-round towards the moving target would be necessary at the end of the interception that the missile would be incapable of providing the required lateral acceleration and would go wide. The control system is therefore arranged to steer towards the future position of the target by a method known as "proportional navigation."

There is a slightly different kind of homing system

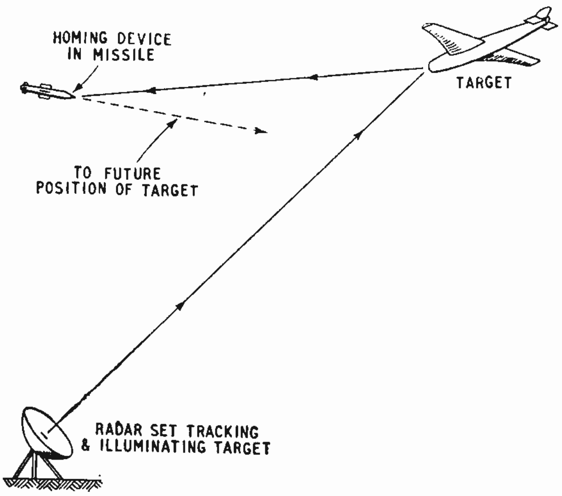


Fig. 2. Guidance system known as "semi-active homing".

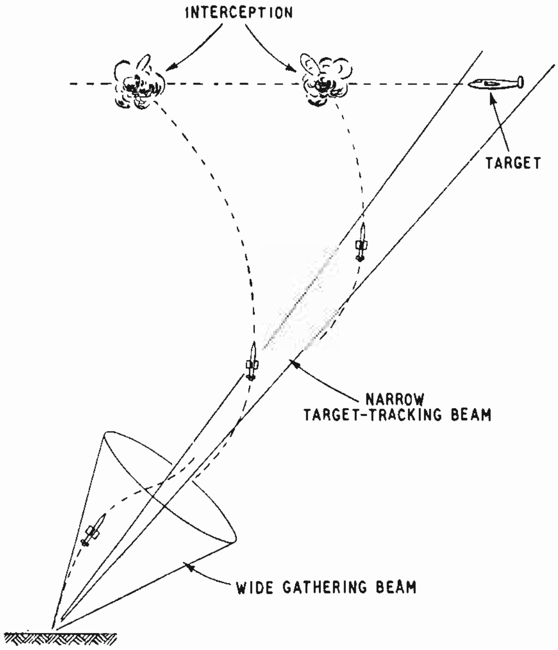


Fig. 3. The "beam-riding" system, permitting several missiles to be launched into the same beam.

in which the missile carries its own radar transmitter (known as "active homing") but this, of course, adds considerably to the weight and complication of the airborne equipment.

The third method of guidance described by Mr. Stephens is called "beam riding" and the principle here is that the missile is guided up the beam of a radar set which is automatically tracking the target (see Fig. 3). Alternatively the beam may be produced by a separate transmitter whose aerial position in azimuth and elevation is automatically controlled by the radar set. The airborne electronic equipment continuously measures the deviation of the missile from the centre-line of this beam and applies appropriate correction signals to the control surfaces to keep the missile flying as close to the line as possible. The measurement is achieved by virtue of the fact that the beam has minimum field strength in the centre, increasing towards the outside, and changes of position of the missile inside it produce corresponding changes of signal strength in an aerial system. A wider beam of the same kind is used to "gather up" the missile in the initial stages of launching and guide it towards the main beam. To fire the missile straight into the very narrow main beam would, of course, be extremely difficult.

It appears that the "beam riding" system is used quite extensively for guidance purposes, and this may be because it has the important practical advantage of allowing a whole series of missiles to be sent up the same beam. Unfortunately it becomes less and less accurate with increasing range because of the widening of the beam, so it is sometimes necessary to use a homing device in the missile to take over in the last stages of the interception.

Automatic Tracking

Mr. Stephens did not enter into details of the actual equipments used for control, but nevertheless a certain amount of information has become available from other sources. For example, there is the technique by which the ground radar sets can be made automatically to track the moving airborne targets without human aid. An accepted way of doing this is to apply a slight rotary movement to the radar beam so that it continuously traces out a narrow cone in the sky. (Usually an electric motor drives an offset dipole within a fixed reflector, or possibly the whole paraboloid.) If the cone is exactly centred on the target the energy reflected back to the radar receiver will be the same for all angular positions of the beam during its rotation and the signal strength will be constant. When the target begins to move away from the centre towards one side of the cone, however, the received signal gets stronger as the beam swings towards it and weaker as the beam moves away. In fact, the received signal fluctuates in strength at the rotational speed of the beam, and the strength of the fluctuations, or amplitude modulation of the signal, becomes a measure of the distance the target has moved off centre. This amplitude modulation is then detected and used as an error-signal to correct the alignment of the radar aerial so that the cone always remains centred on the target.

The angular positions taken up by the aerial as it follows the target will, of course, give the bearing and elevation, and in the Fig. 1 system this information is sent to the computer. The same "lock-and-follow" technique is applied in the airborne equipment of homing missiles (Fig. 2), and here the positional information from the aerial is used for navigating the missile itself. A typical homing head from a missile is shown in the title picture.

The conical scan again figures as an important part of the beam-riding control system (Fig. 3), for providing a "beam" (really a scan) with low field strength in the centre, increasing towards the outside. Here the missile usually has four aerial elements arranged at 90° intervals around its cylindrical body (sometimes built into the trailing edges of the cruciform wing structure), and deviations of the missile from the centre of the cone produce disproportionate signals in these elements. The relative strengths of the signals give the position of the missile relative to the cone-centre in polar co-ordinates (radius and angle) and these values, after transformation into Cartesian co-ordinates, are used to apply the necessary correcting movements to the control surfaces. Different radio frequencies are used for the two conical scans in Fig. 3, and in the missile these are separated to give two sources of signals. An automatic switching device then transfers the control from the wide scan to the narrow scan at the appropriate moment during the flight. The wide scan might have an angular width of about 20° and the narrow scan a width of about 3°.

In all guidance systems, of course, there are a good many side-effects which have to be allowed for if the interception is to be completely successful. Some of these are exemplified in the control equipment of a beam-riding missile produced by Oerlikon in Switzerland for anti-aircraft defence. This weapon (Fig. 4) is about 20ft long and 16in in diameter, and can be steered to a height of nearly 50,000ft. It has cruciform wings which can be moved backwards and forwards to compensate for changes in weight, lift and centre of gravity during flight, while the steering is done by deflecting the propelling nozzle and a cruciform set of fins at the rear. The control equipment on the ground takes the form of three wheeled vehicles—a radar set for tracking the target, a separate beam transmitter and a computer van (Fig. 5).

Correction Device

One of the spurious effects which have to be corrected is the undesired displacement of the missile from the centre of the beam which must occur when the beam is moving, and a computer is necessary to compensate for this. Another computing device is used for limiting the speed of movement of the beam-transmitter aerial so that there is no danger of losing control by swinging the beam too quickly for the missile to follow. Then there are problems resulting from the parallax phenomenon. In anti-aircraft operations the missile battery would be warned of the approach of hostile aircraft by a distant radar system, which would send through information on the position of the target for controlling the aerials of the radar set and beam transmitter. Because of the different points of observation of the distant radar and the local radar set there would be a parallax error in the information, so again a computing device is necessary for correction purposes. The same sort of parallax error also occurs between the local radar set and the beam transmitter controlled by it, and another correcting device is used here in the automatic positional control system which links the two equipments.

In the missile itself, errors in the guidance signals could be introduced by the missile "rolling," or rotating about its longitudinal axis in flight, for this would upset the angular positions of the aerial elements relative to the "beam." The trouble is overcome not by preventing the missile from rolling but by transforming the information on the missile's position from space co-ordinates into co-ordinates relative to the missile itself. A gyroscope is used in the transformation computer, and the result is that the missile's response to guidance signals becomes independent of its angular position. Another gyroscope is incorporated for controlling "pitch" and "yaw" movements.

The steering-fin deflections of the Oerlikon missile are made by an electro-hydraulic servo-mechanism, and this system is, in fact, common to

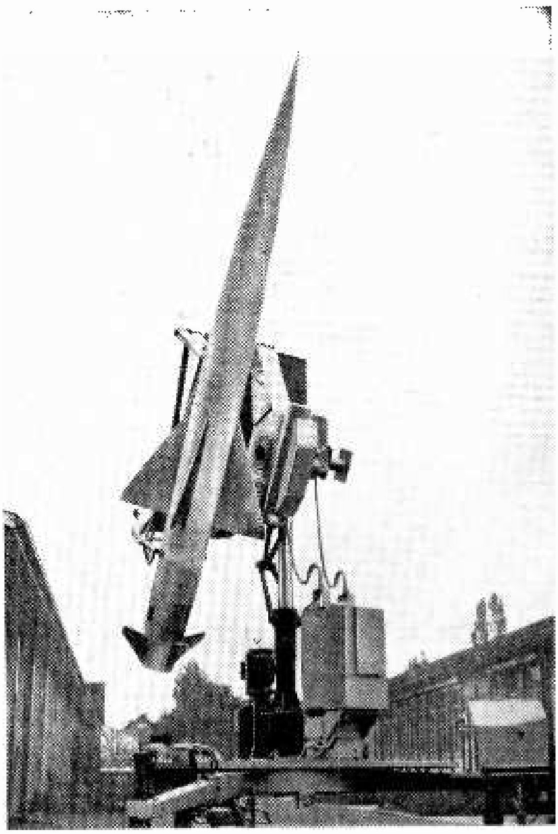


Fig. 4. A "beam-rider" missile on its launching ramp. (This and Fig. 5 by courtesy of "Flight.")

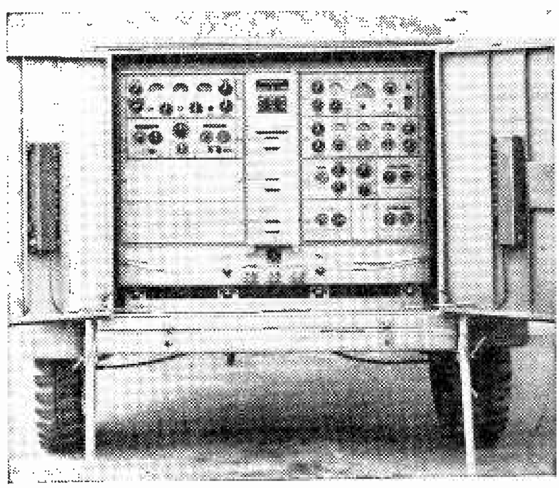


Fig. 5. Mobile control and computing equipment used in conjunction with the Fig. 4 missile.

a great many types of guided weapons. Usually the guidance signals are amplified by a power amplifier and then used to operate mechanical valves which control the flow of hydraulic fluid into small jacks driving the fins. The servo loop is closed by a feedback circuit which sends positional information from the fins back to the electronic servo amplifier.

Very little is known about the actual electronic circuitry used in missile control systems, but the form of construction is generally based on printed or potted circuits with wired-in miniature or sub-miniature valves. The valves in particular have to be "special-purpose" types capable of withstanding the effects of shock, vibration and acceleration, and the equipment as a whole must be designed for working under high-temperature conditions. Many of the developments in valves, components and sub-assemblies which *Wireless World* has reported over the past few years have, in fact, been stimulated by the special demands of guided-missile work, and even if this work is never used for its intended purpose (which is to be hoped) it certainly will not have been wasted.

LOW-VOLTAGE STABILIZATION

Use of Special Secondary Cells

RADIO people have naturally got into the habit of thinking of voltage stabilizers as glow-discharge valves operating somewhere in the region of a hundred volts. It is therefore interesting to hear of a new kind of stabilizer, working on a different principle, which gives a stabilized voltage as low as 1.5 volts. Apart from the obvious applications in stabilizing valve filament supplies (and heater supplies, if they are d.c.), the device looks quite promising for use in the cathode circuits of valves in place of the usual bias resistor and capacitor. The advantage here is that it will give a bias voltage that is almost independent of the cathode current, and this may be particularly useful in Class-B amplifiers and other valve circuits where it is sometimes necessary to provide a separate bias supply.

The new stabilizer, which is made by a Belgian firm, L'Accumulateur Etanche, of 113 rue du Dobbelenberg, Brussels, is actually a form of nickel-cadmium secondary cell. It has a nickel anode, a cathode composed of cadmium and cadmium oxide, and a "separator" consisting of a non-conducting grid impregnated with electrolyte, the whole assembly being enclosed in a steel case hermetically sealed with plastic material. When current passes through the cell the cadmium oxide in the cathode is reduced to cadmium, while at the anode oxygen is evolved. This oxygen passes through the separator to the cathode, where it once again oxides the cadmium which has already been produced by the electrolytic current. As this process is absolutely cyclic no excess gas is formed and the internal pressure remains constant, and this is what makes it possible to seal the cell hermetically and make it into a practical radio component.

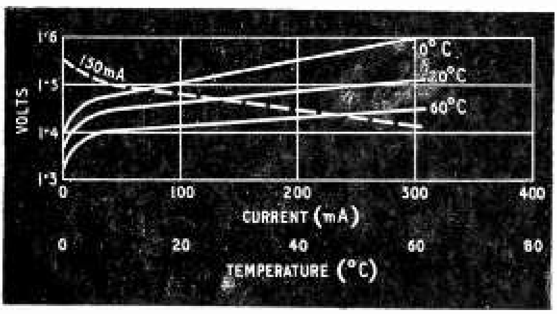


Fig. 1. Stabilization characteristics of the cell with varying current and varying temperature.

A potential is set up at the cathode by the reduction of the oxide and another at the anode by the effect of the evolution of oxygen on the nickel. These two potentials are very little affected by the current flowing, so that the voltage across the terminals of the cell is practically independent of the current which passes through it. The actual characteristics of the stabilizer can be seen from Fig. 1, which shows the voltage at the terminals with varying current for three constant temperatures (full-line curves) and also the voltage with varying temperature and constant current (broken-line curve).

Two versions of the cell are available, each having a range of types with current ratings from 20 mA to 1 amp. The first version is notable for its low impedance, which is 1 ohm or less, depending on the type. This impedance is practically independent of the frequency and is also independent of the current as long as the maximum amplitude of the alternating current is smaller than the direct current passing through the cell. The second version of cell is characterized by the ability to store a certain amount of electrical energy for a short time to tide over possible breakdowns in the mains supply. This is done by including nickel oxide in the anode, and as a result the cell will maintain a voltage of 1.2 volts at maximum current output for a period of one minute.

It goes without saying that several of these stabilizer cells can be connected in series or parallel to make up required voltages or currents. The life of the cells is claimed to be about 10,000 hours.

ELECTRONICS LABS. AT MANCHESTER

THE first building of several planned to form a new science centre for the University of Manchester was completed a few months ago for the electrical engineering department.

There are two main electronics laboratories in the new building, each large enough for fifty students to have working space. One is reserved for elementary electronics and caters for first and second year electrical engineering students, all second year honours physicists and some mechanical engineering and metallurgical students. The other laboratory covers the more advanced electronic experiments—transistor characteristics, transients in long lines, delay lines, pulse generation and waveform shaping, klystron, magnetron and microwave techniques to mention a few. In both laboratories approximately eight to ten feet of bench space is allocated for one experiment usually conducted by two students working together.

In addition there are several smaller laboratories entirely for research. One of these contains an experimental point-contact transistor digital computer developed and constructed in the department.

One floor is devoted exclusively to digital computers and has two computing machines, laboratories and smaller rooms for mathematical and electronic circuitry research. A course in electronic computer circuit technique is available for the final year honours men.

Precision Photographic Timer

COMPENSATED CIRCUIT BASED ON THE MILLER INTEGRATOR

By J. G. THOMASON, B.Sc.

THE simpler electronic timing circuits use the technique of allowing the charge on a capacitor to leak away through a resistor, defining an interval by the time taken for the voltage to rise (or fall) from one preset value to another. An example of this type of circuit is shown in Fig. 1. The initial voltage on the capacitor C is set at $-e_n$ by closing the contact A and when this contact is opened, the capacitor passes current to earth via resistor R losing its charge. The second preset voltage, e_t is the grid voltage at which the valve turns on just enough current to operate the relay, giving a signal that the interval has ended.

This circuit is not particularly reliable since, on opening A, the grid voltage rises exponentially on the curve P in Fig. 2 and is only changing slowly at the time T_1 when the valve is turned on. Small changes in e_t and changes in relay characteristics can therefore have a considerable effect on the interval T_1. The circuit is improved in this respect by returning resistor R, not to earth as shown in Fig. 1, but to the positive line e_p. The grid voltage now rises on the large exponential shown by curve Q in Fig. 2. It is seen that the grid voltage is now changing quite rapidly at e_t, giving the interval T_2. However, the interval T_2 is usually less than the time-constant CR, whilst T_1 is usually greater (see Fig. 2); and in a photographic timer where intervals of up to say 100 seconds are required, it is uneconomical to use a circuit which requires components to produce a time-constant of 100 seconds or higher.

Both the difficulties of uncertainty in interval length and large time-constant are overcome by the use of the Miller integrator circuit. This circuit is well suited to many timing applications, from minutes down to microseconds.

A desirable feature of a photographic timer is a facility for automatically adjusting the nominal time intervals to allow for variations in enlarger lamp brightness resulting from fluctuations in mains voltage, and this has been incorporated.

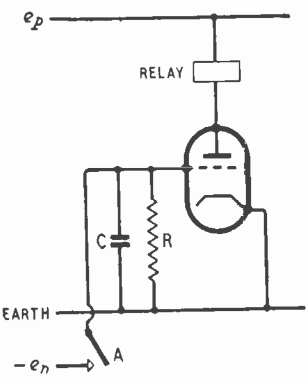
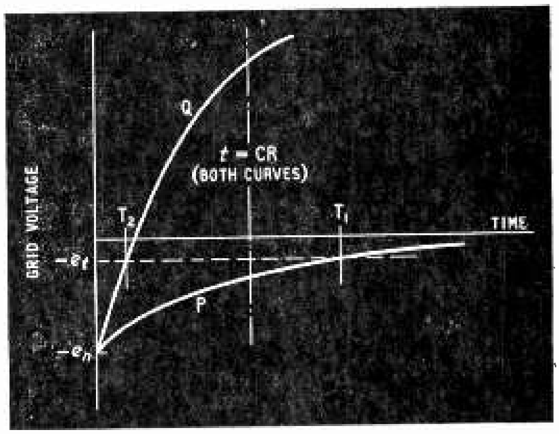


Fig. 1. Simple timer circuit depending on the discharge of C through R.



Above: Fig. 2. Operating conditions (P) for the circuit of Fig. 1 and (Q) when R is connected to e_p.

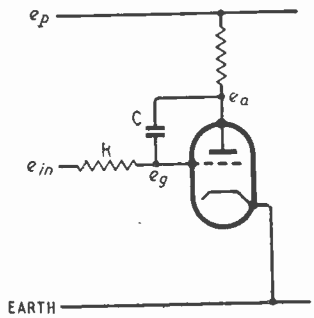


Fig. 3. Basic Miller integrator circuit.

The complete timer to be described gives 11 intervals, employs 5 conventional valves and consumes less than 25mA at 300v.

Miller Integrator Circuit.—The basic Miller integrator circuit is shown in Fig. 3, with biasing and decoupling arrangements omitted. The capacitor C introduces negative feedback, forming a type of circuit whose operation is readily explained by means of the "virtual earth" concept. If the valve in Fig. 3 gives a high gain, then voltage changes at the anode of, say, tens of volts would be provided by grid voltage changes of tenths of a volt. If all the other voltage levels in the circuit are in tens of volts then the grid voltage e_g may be regarded as constant, whatever the anode voltage e_a. For this reason and others, the grid behaves as though it is fixed at or near earth potential and is known as a virtual earth. This means that for a constant input e_{in} to the circuit, a constant current may be assumed to flow down R. This current must all flow into capacitor C (since there is no grid current), charging it up at a constant *rate.* It is this linear voltage change compared with the exponential (Fig. 2) which gives the Miller integrator its superiority over the non-feedback circuit.

The practical version of the Miller integrator used in the timer has a nominally constant positive voltage for the input e_{in}, passing a constant current $(e_{in} - e_g)/R$ into the capacitor C. The direction of this current is such as to cause the voltage on the upper plate of the feedback capacitor to fall, at a rate given by current/capacitance, i.e. $(e_{in} - e_g)/CR$ volts per sec. At the beginning of the interval the anode is held at + 200V and during the interval, falls linearly from this value to + 100V.

The anode should not be started at the full h.t. voltage or initially there would be no voltage drop across the anode load resistor, no anode current and therefore no gain. Also, should there be a sudden drop in h.t. voltage capacitor C would transmit the drop to the grid, but the feedback would be powerless to restore the anode and grid voltages since the anode voltage would now need to be above the h.t. voltage. Similarly, the lower preset voltage should also be chosen within the range of anode voltages where the valve is giving high gain, i.e. just above the pentode "bottoming" voltage.

If the start and finish voltages are e_1 and e_2 respectively, the interval T, which is equal to voltage travel divided by voltage rate, is given by:

$$T = \frac{e_1 - e_2}{e_{in} - e_g} CR$$

It is seen from this equation that, for given values of C and R, according to the approximate virtual earth theory outlined, T can be made as large or as small as desired. In this application the object is to secure a large value of T without using large values of C or R. A maximum interval of 100 seconds is required, and it would be inconvenient to use a circuit which needed a value of CR as high as this, say 10MΩ with 10μF. Electrolytic capacitors have too small a leakage time-constant and 10μF in paper capacitors would be expensive and bulky. Resistors of value much higher than 10MΩ usually have poor accuracy and are liable to drift in value.

The limitation of the extent, to which T can be increased for a given value of CR, according to the equation above, lies in the approximations made when formulating the virtual earth principle. If e_1 and e_2 assume the practical values of + 200V and + 100V respectively, the interval T is given by $100/(e_{in} - e_g)$ times CR. To make T equal to, say, 100CR, $(e_{in} - e_g)$ would have to be 1V. Now e_g is not really constant—there must always be small grid voltage changes as the anode voltage changes from + 200V to + 100V, and for a valve gain of, say, 100, the grid voltage change will be 1V. Also, the mean value of e_g might differ by up to 0.3V if the valve is replaced. These voltages are small compared with the anode voltages but are, of course, comparable with the 1-V input required for T to equal 100 CR. At the beginning of the interval, the anode voltage rate would be 1/CR V/sec., but would be reduced to zero at the end due to the 1-V rise in e_g. This would result in the "linear" anode voltage change assuming an exponential form, similar to curve P in Fig. 2, with the attendant uncertainties.

The compromise chosen is to make $(e_{in} - e_g)$ nominally 4.7V, making T equal to 21.5 CR. For the 100-sec. interval CR is then 4.7 sec.; a 4.7-MΩ resistor with a 1-μF capacitor is used. The input current is then 1 μA and it is necessary to select a valve whose grid current is small compared with this. The EF37 is known to be very good in this respect, grid currents of less than 10^{-11} ampere being possible when it is run at reduced ratings. This valve is operated with 50V on the screen and a mean anode current of 100 μA. Under these conditions the measured grid voltage change is 0.33 V when the anode voltage changes from + 200-V to + 100V (gain of 300), reducing the initial input current from 1 μA to 0.93 μA, only a 7% drop.

A potentiometer is provided to adjust the nominal 4.7-V input to allow for this drop and also to enable tolerances in e_1, e_2 and C to be accommodated. The complete circuit is shown in Fig. 4, where it is seen that a cathode resistor is used in order to make the mean value of e_g zero—this is necessary for the action of the mains voltage compensator, which requires the input voltage to be determined by e_{in} only, i.e. without the addition of any grid bias voltage. An additional advantage of arranging for the mean grid voltage to be zero is that leakage currents will be negligible and no special insulation to earth is required for the grid wiring, the 1 μF capacitor mounting, or the resistor switch.

Trip Circuit.—The trip circuit is required to operate a relay immediately the Miller integrator anode reaches + 100V during its linear fall from + 200V. The "long-tail pair" circuit is suitable for this application since the working grid voltages, where valve current is turned on or off, may conveniently be adjusted to be at + 100V. Fig. 4 shows the circuit arrangement. In the quiescent period when the Miller integrator anode is held at + 200V by the relay contact A1, the 6SN7 triode (b) conducts 10mA, since its grid is held at + 100V, and the cathode "follows" this voltage, with a 10-kΩ common cathode load resistor. Triode (a) cannot conduct since its anode circuit is broken by the relay contact A2. When the "start" button is presssed, triode (a) conducts instead of triode (b) since grid (a) is returned via the 1-MΩ resistor to a + 110-V tap on the resistor chain. The relay in anode (a) circuit is energized and holds-in via contact A2 so that the start button may be released. Simultaneously contact A1 opens allowing the Miller integrator valve anode to commence the linear fall in voltage. Also contact A3 closes, applying the mains voltage to the enlarger lamp socket. The diode (a) does not conduct until the Miller integrator valve anode falls to + 110V, when more anode current in the EF37 is turned on via diode (a) and the 1MΩ resistor, clamping the grid of triode (a) to the Miller integrator valve anode. As this common voltage falls to + 100V, the 10mA flowing in the 10-kΩ cathode load is shared approximately equally between triodes (a) and (b), and after only a volt or so further fall in the voltage impressed on grid (a), the relay is de-energized and the interval ended, the circuit rapidly returning to the quiescent conditions.

Mains Voltage Compensator.—The light output of a normal electric light bulb used in a photographic enlarger varies as some high power of the applied voltage; approximately the fourth power under usual conditions. It is helpful in standardizing printing conditions if the nominal intervals given by a timer can be automatically compensated to take account of this variation. A simple device with a high power law characteristic which springs to mind is the semi-conductor "Atmite" disc* used for surge suppression with relays. The property of this material is that the current passed is proportional to between the fourth and fifth power of the applied voltage.

The most straightforward method of using an "Atmite" to give compensation would be simply to connect it in place of the resistor R in Fig. 3. The current fed in to the capacitor C via the virtual earth would then be proportional to, say, the fifth power of e_{in}, and if e_{in} is derived from the h.t., then this current, and therefore the rate of fall of the voltage on C, would be proportional to the fifth power of the mains voltage. The nominal interval would then be inversely proportional to the fourth power of the mains voltage, the fact that the nominal 100-V fall in capacitor voltage is proportional to the mains voltage reducing the power law by one. This arrangement would not be convenient to design, however, since either a separate capacitor for every interval would be required or a carefully set resistor chain using non-preferred values for supplying the necessary values of e_{in}.

The method used is to make e_{in} itself proportional to the fifth power of the mains voltage so that one value of C only is needed, and to select the intervals by using different values of R. Fig. 4 shows the 6SH7 high-slope pentode, triode-connected, used in the "anode follower" circuit. The grid acts as a virtual earth and the current fed-in passes via three 24-V "Atmite" discs from a subsidiary 85-V negative line, provided by the 6H6 diode (b). The input current, and therefore the 6SH7 anode voltage, are proportional to the fifth power of the mains voltage.

The nominal 4.7-V Miller integrator input is obtained from a resistor chain fed by the 6SH7 anode, using the 2.5-kΩ potentiometer shown in Fig. 4 to vary this voltage by ± 50%. The high power law of the "Atmites" means that the 85-V negative line will be fairly critical in value to set the 6SH7 anode at + 120V. The exact value of a.c. input to the 6H6 (b) will depend on individual component choice, and the 8.2-kΩ resistor shown in Fig. 4 could have any value between zero and 15kΩ and should be set by trial and error. Note that the "Atmites" should be mounted at a cool place in the layout.

Circuit Details.—The 250-0-250V, 6.3V 2A transformer, 6X5 rectifying valve and 16-μF electrolytic smoothing capacitor provides the power supply. The single 16-μF capacitor gives adequate smoothing since the 6SH7 and EF37 both operate with negative feedback, whilst the 0.02-μF capacitor filters h.t. ripple from the 6SN7 grid. The current drain from the −85V line is only 55μA and the single 0.5-μF capacitor gives adequate smoothing.

All intermediate voltages are obtained from a single resistor chain passing 7mA. This current is passed through the cathode resistor of the EF37 compensator valve enabling a 330-ohm resistor to be used, which is low enough to give only a small loss in gain.

An 11-position Yaxley type switch is used to select the intervals and the particular values chosen are the round numbers corresponding to equal logarithmic spacing between 1 sec. and 100 sec.

* "Atmite" discs are manufactured and supplied by the Automatic Telephone and Electric Company, Ltd., Strowger Works, Liverpool, 7. A suitable type is the L275702 costing 2s. 6d. The type of disc used is not critical; in any case adjustment of the operating current is necessary as described in the text.

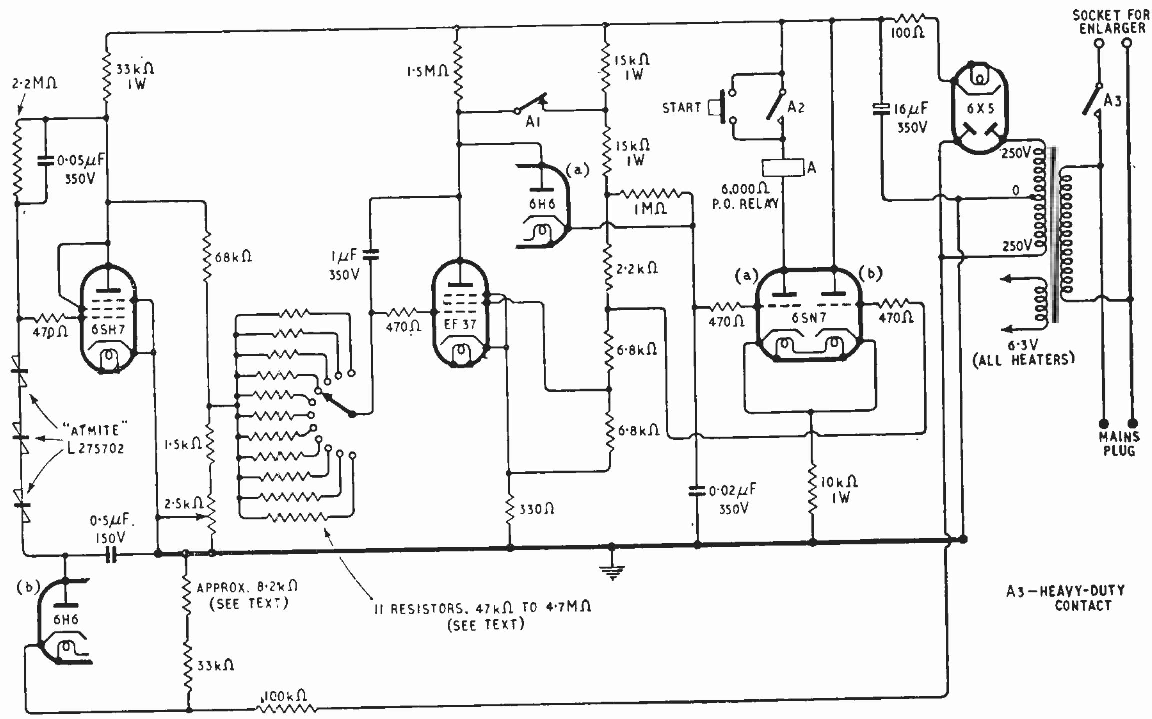


Fig. 4. Circuit of complete photographic timer. Valve types are not critical and alternatives are given in the text. Resistor ratings are ½ watt unless otherwise marked.

TABLE

Switch Position	1	2	3	4	5	6	7	8	9	10	11
Time interval (sec.)	1	1·5	2·5	4	6	10	15	25	40	60	100
Exact Resistor Value	46·5kΩ	69·8kΩ	116kΩ	186kΩ	279kΩ	465kΩ	698kΩ	1·16MΩ	1·86MΩ	2·79MΩ	4·65MΩ
Nearest Preferred Value	47kΩ	68kΩ	120kΩ	180kΩ	270kΩ	470kΩ	680kΩ	1·2MΩ	1·8MΩ	2·7MΩ	4·7MΩ
Timing Error %	+1·1	−2·6	+3·2	−3·3	−3·3	+1·1	−2·6	+3·2	−3·3	−3·3	+1·1

Switch Position	1	2	3	4	5	6	7	8	9	10	11
Time Interval (sec.)	1	1·4	2	2·8	4	5·7	8	11	16	23	32
Nearest Preferred Resistor Value	47kΩ	68kΩ	91kΩ	120kΩ	180kΩ	270kΩ	390kΩ	510kΩ	750kΩ	1MΩ	1·5MΩ

The table shows, for each switch position, the interval, the exact value of resistor required and the nearest preferred value. The time error caused by the preferred values is also shown, assuming an input voltage of 4.65V rather than 4.7V in order to make the errors more evenly distributed.

An alternative set of intervals spaced by $\sqrt{2}$, or half a photographer's "stop" are also given with suggested values of resistance, assuming an input of 4.7V.

Setting up and Calibration.—After checking the circuit, the first thing to do is to ensure that the Miller integrator 1μF capacitor does not leak. Some means of measuring the EF37 anode voltage is needed—either a d.c. valve voltmeter, a 20,000Ω/V type of Avometer or similar on 1,000-V range, or a 0-100 microammeter used in series with the 1.5MΩ anode load. Disconnect the 10th resistor, and, using the 11th switch position, start the timer using the meter to show when the anode voltage has fallen to + 150V. Now quickly switch to the 10th position and note the rate of change of anode voltage due to leakage only. 1V in 10 seconds represents a 10% error on the 100-sec. range but most present-day capacitors can do very much better than that. Next check that the 6SH7 anode voltage is between +110V and +120V at the time of day it is proposed to use the timer. If necessary, correct this voltage by adjusting the resistance preceding the bias rectifier 6H6(b).

Calibration is not easy without instruments, and the simplest method is to beg, borrow or "bridge" an accurate 4.7-MΩ resistor for the 100-sec. position and, using a stopwatch, set the 2.5-kΩ potentiometer until this interval is correct—again at the time of day when most enlarging will be done.

Alternative Valves.—The circuit is not critical in valve types; those specified were used since they happened to be available cheaply. More affluent constructors could use modern miniature valves, for example:

Compensator: EF91, 6AM6, 6F12, Z77, SP6, HP6, etc.

Miller integrator: EF86, Z729, 6BR7, 6BS7.
Double diode: 6AL5, EB91.
"Long-tail pair": 12AU7, ECC82.
Rectifier: 6X4G, EZ90, U709.

No circuit modifications would be involved with these valve changes.

CLUB NEWS

Birmingham.—At the meeting of the Slade Radio Society on February 3rd, T. P. Douglas (G3BA) will speak on "Some practical aspects of amateur v.h.f. construction." In addition to the normal fortnightly gatherings in February, there will be a special d.f. meeting on the 24th. Meetings are held at 7.45 at the Church House, High Street, Erdington, Birmingham, 23. Sec.: C. N. Smart, 110, Woolmore Road, Erdington.

Birmingham.—The next meeting of the recently formed Midlands Group of the British Amateur Television Club will be held on February 9th at the address of the secretary, F. J. Rawle, 16, Kings Road, New Oscott, Sutton Coldfield, Birmingham, 23.

Cleckheaton.—A. Thompson (G2FCL), who is dealing with two-metre transmitters at the meeting of the Spen Valley and District Radio and Television Society on January 25th, will discuss two-metre receivers at the February 8th meeting, which will be held at 7.30 at the Temperance Hall, Cleckheaton. Sec.: N. Pride, 100, Raikes Lane, Birstall, near Leeds.

Coventry.—At the meeting of the Coventry Amateur Radio Society on February 13th, L. W. Gardner (G5GR) will speak about aerials and switches. Meetings are held fortnightly at 7.30 at 9, Queens Road. Sec.: J. H. Whitby (G3HDB), 24, Thornby Avenue, Kenilworth, Warwicks.

Edinburgh.—Radio interference and the amateur will be discussed by W. T. Bell, of the G.P.O. Engineering Department, London, at the meeting of the Lothians Radio Society on February 9th. A fortnight later Chief Inspector N. W. Bruce will talk about police radio. Both meetings begin at 7.30 at 25, Charlotte Square, Edinburgh. Sec,: J. Good (GM3EWL), 24, Mansionhouse Road, Edinburgh, 9.

LOUDSPEAKER ENCLOSURE DESIGN

By E. J. JORDAN*

2.—A Cabinet of Reduced Size With Better Low-frequency Performance

IN the first part of this article the features of performance and design of the principal methods of mounting a loudspeaker were reviewed. These may be briefly summarized in order of merit, as follows.

Full Horn.—Acoustically this is the ideal method of loudspeaker mounting. It provides excellent air loading on the cone, is devoid of self-resonance and possesses a high radiation efficiency down to any desired frequency, being limited only by the horn dimensions. The disadvantage of the horn is the very great size required for effective operation down to very low frequencies.

Absorbing Labyrinth.—This again presents excellent resonance-free air loading on the loudspeaker cone, and in this respect is comparable to the horn. It is effective down to any desired frequency, being limited, like the horn, by its dimensions. Unlike the horn, however, the disadvantage of this system is the falling efficiency at low frequencies due to the approach to constant-velocity conditions, although this may be partially compensated for in the amplifier. A labyrinth capable of good absorption down to very low frequencies is still rather big.

Reflex Enclosure.—The advantage of the reflex cabinet is that excellent damping is applied to the loudspeaker cone at its resonance where it is most required. A further point in its favour is that it is relatively simple to construct. The bass response from a reflex enclosure will have an efficiency somewhat higher than that from a labyrinth, and for a given bass extension, will be smaller, although it still makes a rather dominating piece of furniture in the drawing-room. The response will not be so smooth as for a labyrinth due principally to the upper of the two resonances common to this type of mounting. If very much bass boost is applied the reflex enclosure will tend to sound boomy, also port radiation at the lower of the two resonances will tend to cancel that from the cone.

Wall Mounting or Large Flat Baffle.—This type of loudspeaker mounting presents a lower impedance to the rear of the loudspeaker cone than any other, therefore with the exception of horn loading, this system has the highest efficiency among direct radiators. The low acoustic damping applied to the cone, however, makes necessary the use of a loudspeaker unit having a high degree of electro-magnetic damping, if excessive cone velocity is to be avoided, in which case the relative efficiency of the system at low frequencies is lost and its performance will be similar to that of a labyrinth.

*Goodmans Industries Ltd.

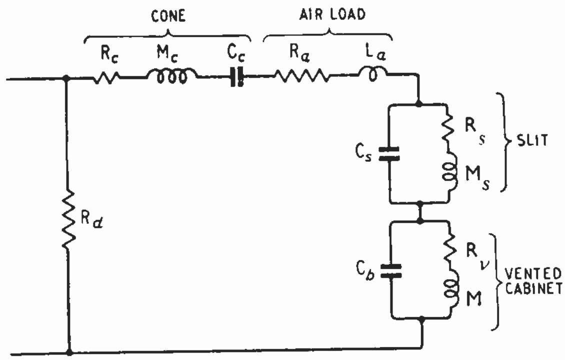


Fig. 8. Electrical analogue of loudspeaker-cabinet system incorporating an additional restricted aperture in front of the cone. M_s and R_s are the mass and resistance associated with the slit and C is the compliance formed between the cone and the inside face of the orifice.

Recent Trends.—It has for years been the ambition of designers to produce a loudspeaker system having the performance of a horn and the dimensions of an orange box. (We will not say a matchbox since an 80-piece orchestra coming therefrom would stretch the imagination too far.) Many audio engineers have examined the possibilities of small compromise horn-type enclosures since these may be capable of very impressive reproduction. The writer is not, however, addicted to impressive reproduction preferring to aim for accuracy. The horn cannot be compromised effectively and it can be stated categorically that good reproduction from, say, 50 c/s down to 30 c/s would demand an enormous horn. In any case it is questionable whether such high efficiency is necessary from a given loudspeaker unit. The labyrinth will

SYMBOLS

- C_b = compliance of air in closed cabinet.
- C_c = compliance of cone suspension.
- C_s = compliance of air between cone and front slit baffle.
- L_a = $L_r(\pi r^2)^2$
- L_r = acoustic radiation mass.
- M_c = mass of cone system.
- M_s = mass of air in slit.
- M_r = mass of air in vent or orifice.
- R_a = $R_r(\pi r^2)^2$
- R_c = resistance due to friction in cone.
- R_d = mechanical resistance due to voice coil damping.
- R_r = radiation resistance.
- R_s = viscous resistance of vent.
- R_v = total resistance component of vent % R_r = R_s.
- v = velocity of cone.
- Z_b = impedance due to loudspeaker mounting.
- Z_r = acoustic radiation impedance.
- ω = $2\pi f$.

C.g.s. units for mechanical and acoustical quantities, and e.m. units for electrical, have been assumed throughout.

secure the same downward extension of bass and freedom from resonance as a horn many times its size. Admittedly the amplifier is called upon to supply a few more low-frequency watts, but for normal requirements this is well within the capabilities of any of the well-known 10 or 15-W amplifiers. Even if an additional bass boost circuit has to be fitted, the cost and trouble is still hardly comparable to that of horn construction.

Space-saving considerations give the reflex enclosure a very great advantage over the other systems mentioned; in addition the acoustic characteristics are very good, and the principle suggests itself as being more amenable to compromise than that of the horn. A great deal of experimental work has been directed therefore to reducing still further the size of a reflex enclosure and improving its performance.

We saw in the previous article that, if its size is reduced, the reflex enclosure will present a higher impedance to the rear face of the cone at all frequencies, and, due to the increased impedance of a smaller port, the upper resonant frequency will become unduly prominent. We mentioned also that facing the cone into a restricted aperture or slit would reduce the resonance. This may now be explained by considering the analogous circuit (Fig. 8). Here the impedance due to the mass and resistance components of the slit appears as the series M_s and R_s shown. Now the lower resonant frequency

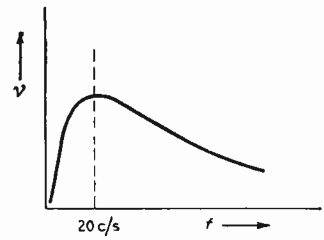


Fig. 9. General form of velocity/frequency response of cone required at very low frequencies.

will be substantially due to $R_cM_cC_cR_aM_sR_sM_vR_v$ in series and the upper resonant frequency due to $R_cM_cC_cR_aM_sR_sC_b$ in series. Since the impedance of M_s and R_s forms a greater proportion of the total mass reactance and resistance in the second case the upper resonance f_2 will be lowered both in frequency and amplitude to a greater extent that f_1 (see Fig. 11). A vertical slit also has the advantage of diffusing the higher frequencies horizontally due to its approaching a line source.

The condemning feature of the slit (or any other reduced orifice in front of the loudspeaker cone) is that in conjunction with the cavity (C_s) formed between the cone and the inside face of the material forming the slit, it constitutes a Helmholz resonator, which makes itself heard very forcibly somewhere in the middle frequency (300 c/s-700 c/s) range. Standing waves also occur between the cone and the inside face, causing irregularities noticeable in the treble (1,000 c/s-5,000 c/s). We may, therefore, frown upon slits.

It is better to form the impedance M_s and R_s behind the cone by fitting, for example, a cowling† over the rear of the loudspeaker which has an outlet of restricted area, or, as is described in a patent held by Murphy Radio, a corrugated cardboard cylinder is fitted over the rear of the speaker, so that the rear radiation must pass through the small tubes so formed.

These systems represent a very considerable improvement over the slit, although they still tend to introduce slight irregularities in the response. It is surprising, how efficiently even a cardboard drum can behave as a tubed pipe. Nevertheless it must be said the performance of these enclosures is very good for their size and at low frequencies is comparable to that of a full-sized labyrinth. Like the labyrinth they present a high resistive impedance to the rear of the loudspeaker cone; their efficiency is therefore low. It will be seen that M_s and R_s in the analogous circuit will tend to reduce the cone velocity at all frequencies. These components do therefore constitute a further loss of efficiency.

The reader should now be well acquainted with the principles involved in the design of the basic type of loudspeaker mounting and with the problems encountered, if these designs are comprised. The question of size is a very important one; there is a demand for a really high-quality sound-reproducing system that is small enough to be unobtrusive in a small lounge or flat.

A good approach to the design of such a system would be to state exactly what was meant by "really high quality" and to define the acoustic properties of the system in terms of cone velocity. This can be expressed as a function of mechanical impedance, which in turn may be translated into an analogous electrical impedance. The problem then resolves itself into the solving of the electrical circuitry. This approach led to the design of an enclosure having the desired performance and, proceeding as above, we shall endeavour to show the derivation of this design.

Enumerating the principal qualities of an "ideal" enclosure, we have:—

(1) Frequency response extended down to at least 20 c/s.

(2) Complete absence of resonances above this frequency.

(3) Small size.

(4) Efficiency as high as possible in keeping with (2) and (5).

(5) Low distortion.

In order to satisfy requirements (1), (2) and (4) the cone velocity must increase progressively as the frequency is lowered to 20 c/s. Therefore, the enclosure must load the cone in such a way as to bring the effective cone resonance down to this frequency. There must be also a sufficiently high resistance component in order to satisfy requirement.

(5) By limiting excessive increase of cone velocity due to resonant conditions.

In the analogy, these conditions are fulfilled by the velocity curve shown in Fig. 9, and the corresponding analogous circuit shown in Fig. 10, where inductive and resistive elements are added to the cone circuit.

As we have seen, a convenient way of adding mass to the loudspeaker cone is to load it by means of restricted orifice or vent. It is preferable to couple this air mass to the rear face of the cone, and since, at the resonance of the system (neglecting here any compliance existing between this air mass and the cone) the radiation from the vent will be in antiphase with that from the front of the cone, in order to produce negligible cancellation, the vent

†Patent applied for by Goodmans Industries.

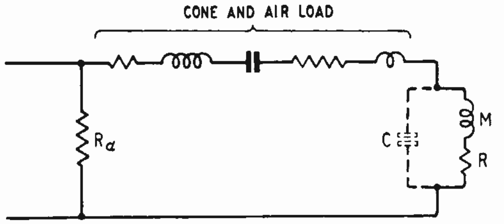


Fig. 10. Analogue circuit elements added to cone to produce response of Fig. 9.

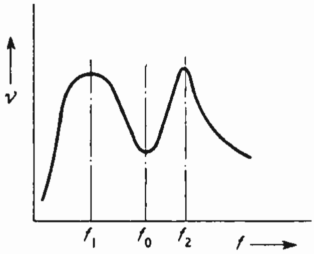


Fig. 11. Velocity/frequency response resulting from the addition of C in Fig. 10.

area must be considerably less than the effective piston area of the cone. Therefore, for a given mass reactance a small vent is preferable to a larger vent with a tunnel. As the orifice is reduced, however, the resistance due to viscosity at its edges is increased relatively to the mass reactance, and, whilst to some extent this is desirable for requirement (5) above, a point is reached where the rise in velocity down to the required frequency due to the action of the added mass is severely reduced, resulting in an undue loss of radiated power at these frequencies. This conflicts with requirement (4) above. These considerations therefore fix the port dimensions within fairly narrow limits, quite irrespective of whether the mass reactance from these dimensions is sufficient to reduce the loudspeaker cone resonance from wherever it is down to the required low-frequency limit. Since the mass reactance of the orifice will increase with frequency, it will be necessary to decouple this mass from the cone at the higher frequencies. This requires a shunt capacitance C in the analogy, which may be of such value, that in combination with the mass reactance ωM will produce an effective mass reactance $\omega M'$ having the value required to lower the effective resonance of the series circuit, *i.e.*, the effective cone resonance by the desired amount. Since the capacitance C performs two functions, its value must be determined with both these in mind. For "decoupling" purposes the circuit must become capacitive as soon as possible above f_1 (Fig.11) which indicates that the resonance of the parallel section f_0 should occur a little above this frequency. We shall see later, however, that it is desirable for f_0 to occur above the free-air resonant frequency of the loudspeaker cone. The effect of C on the effective cone resonance may be seen by considering the susceptance of the parallel section, which is:—

$$B = \frac{\omega^2 CM - 1}{\omega M}$$

and provided this expression is negative the circuit will behave as an effective inductive reactance of magnitude

$$\omega M' = \frac{\omega M}{1 - \omega^2 CM}$$

To lower the effective cone resonance to a frequency f_1 the sum of the above expression, and the effective reactance of the cone must be zero at this frequency.

Effective reactance of cone, $X'_{cone} = \frac{\omega^2 M_c C_c - 1}{\omega C_c}$

By implication $\omega M'$ is positive at ω_1 and X'_{cone} negative at ω_1.

Equating we have $\frac{\omega^2 M_c C_c - 1}{\omega C_c} = \frac{\omega M}{1 + \omega^2 CM}$

Transposing for C we have

$$C = \frac{C_c}{\omega^2 M_c C_c - 1} - \frac{1}{\omega^2 M}$$

Although a value of C may be found from this expression a lower limit is set to its value by its decoupling function. It is vital that the impedance of the parallel section be well decoupled at frequencies above about 50 c/s.

It is evident that the circuit we now have is analogous to a vented enclosure where the component values have been specially chosen to maintain the radiation efficiency down to 20 c/s. In the previous article we showed how a circuit of this type had three critical frequencies f_1, f_0 and f_2 which resulted in a velocity curve as shown in Fig. 11. In the present case f_1 is our required low frequency resonance and in respect of our second requirement for the "ideal" enclosure the resonances at f_0 and f_2 must be eliminated. (f_0 in the present case is not coincident with the cone resonance.)

We have seen that the resonance at f_0 is due

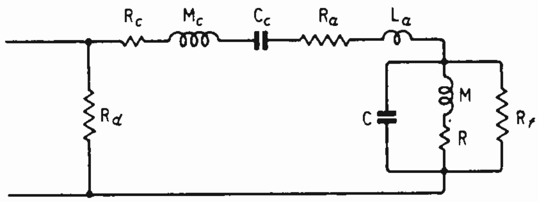


Fig. 12. Complete analogue of final design. R_f is an added acoustic resistance.

to the parallel section where its impedance rises to some high value reducing the cone velocity at this frequency. This impedance rise may, of course, be limited by shunting this circuit with a low resistance R_f, Fig. 12, the low limit of R_f being set by its damping effect at f_1.

It has been found possible to choose values of M, C and R_f that are compatible with all the previous considerations and at the same time are such as to reduce the resonances at f_0 and '$_2$ to negligible proportions.

Let M and C have values producing a reactance characteristic which, relative to that of series components M_c and C_c will be as shown in Fig. 13. The three critical frequencies are shown, and it will be noticed that the reactance of the individual circuits at f_2 is much higher than at f_1. If the effective reactance of M and C in parallel is X_P and this is shunted by R_f, then we may replace this

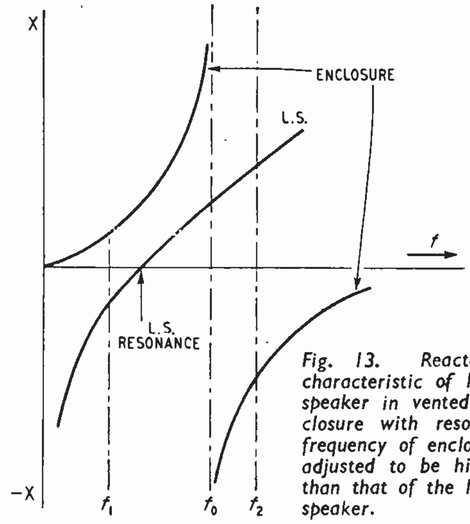


Fig. 13. Reactance characteristic of loudspeaker in vented enclosure with resonant frequency of enclosure adjusted to be higher than that of the loudspeaker.

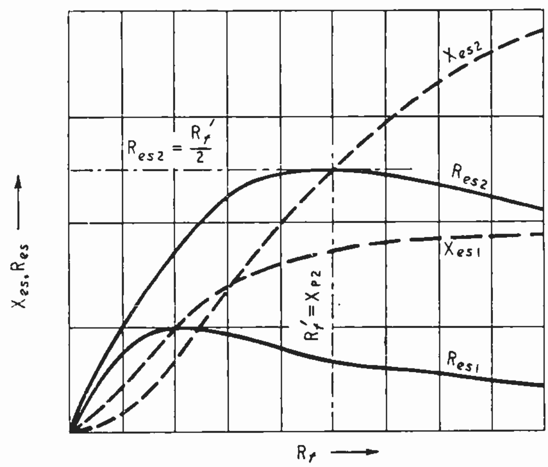


Fig. 14. Variation of X_{es} and R_{es} with R_f for two values of X_P when $X_{P1} < X_{P2}$.

arrangement by an equivalent series circuit consisting of a resistance R_{es} and reactance X_{es} which obey the well-known relationships:—

$$R_{es} = \frac{R_f X_P^2}{R_f^2 + X_P^2} \quad X_{es} = \frac{R_f^2 X_P^2}{R_f^2 + X_P^2}$$

The effect on R_{es} and X_{es} of varying R_f is shown in Fig. 14. The curves have been plotted for two values of X_P, i.e. X_{P1} and X_{P2} corresponding to those shown at f_1 and f_2. It will be seen that the curve R_{es2} reaches a maximum at $R_f = X_P^2$ where its value is $R_f/2$. At this point it will be seen that X_{es2} and R_{es2} are equal and the Q of the circuit under these conditions is therefore 1.

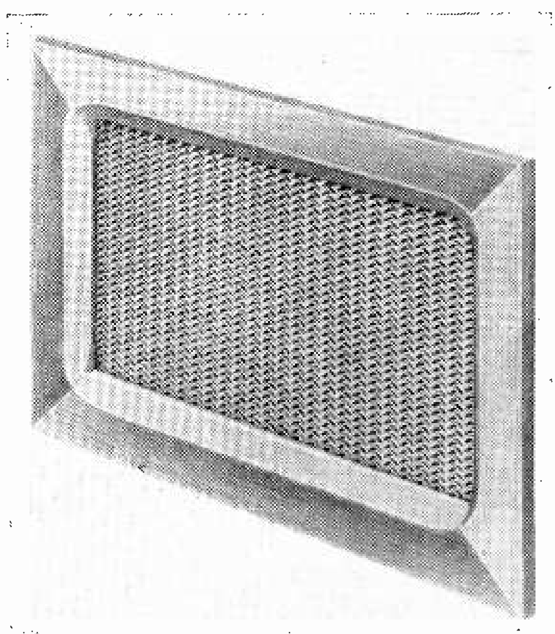
If we now consider a lower value of X_P corresponding to X_{P1} at f_1 we see from the curves that for the value $R_f = X_{P2}$ the Q clearly greater than 1. It is evident from the curves that R_f has a range of values that will produce higher damping at f_1 than at f_2 (and also some values that will produce the opposite effect). The action of the enclosure vector may be summarized by considering the locus of its impedance, which is part of a spiral and is shown in Fig. 15. The presence of R_f will of course alter the actual values of the frequencies f_1 and f_2, but again careful choice of component values enable us to hold f_1 at 20 c/s. We care not for the predicament of f_2.

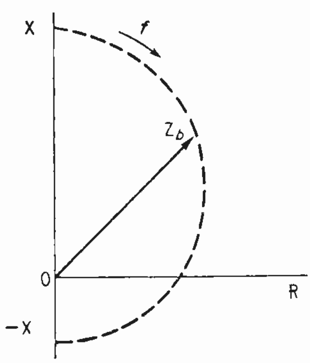
It was decided that the first prototype enclosure based on these principles should be designed for use in conjunction with the Goodmans Axiom 150 Mk. II loudspeaker. Accordingly the values of R_d, R_c, C_c, M_c and R_a in the analogy were determined from the physical constants of this loudspeaker and translated into acoustical terms. From this the dimensions of the enclosure and vent were determined, and an enclosure was constructed accordingly, the resistance being analogous to a resistive air leak in the enclosure walls. The impedance curves for this enclosure are compared in Fig. 16 with those of the reflex cabinet and a true infinite baffle when housing speakers identical to the above. The evidence is fairly conclusive. The effect of closing the air leak (removing R_f) is also shown.

There are a number of methods of forming the resistive air leak, all of them possessing varying degrees of manufacturing difficulty. One method is to make a number of very narrow slits in one or more of the enclosure walls. Another is to cover a relatively large aperture in an enclosure wall with a material of suitable porosity. In any event the resistance is due to the frictional component of the air leak and one of the principal practical difficulties has been to make this frictional component high relative to the mass component which is present in any aperture. In the analogous circuit this mass component appears as an inductance in series with R_f.

From the foregoing principles formulæ have been derived expressing the various cabinet dimen-

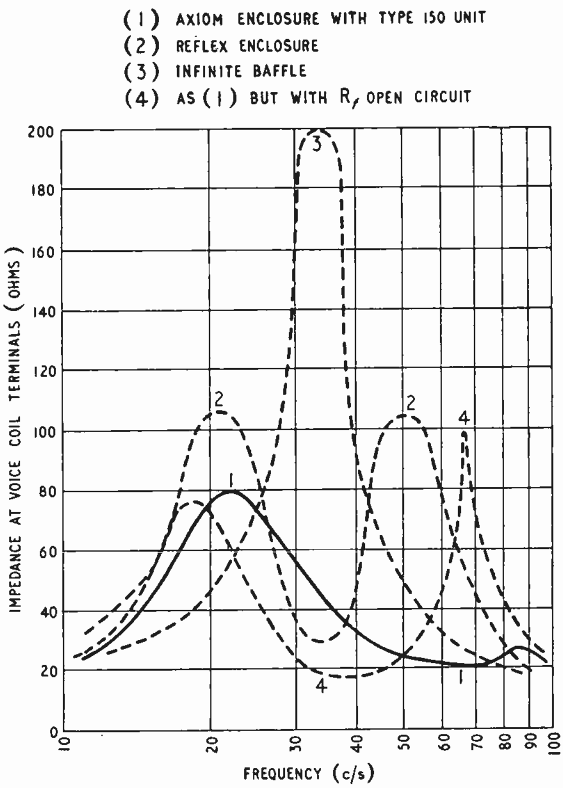
One of a range of acoustical resistance units designed to match Goodmans loudspeakers in cabinets of specified volume.





Left:—Fig. 15. Locus diagram showing variation with frequency of magnitude and direction of enclosure impedance vector.

Right:—Fig. 16. Voice-coil impedance curves of the Axiom 150 unit in the Axiom 172 enclosure and the same loudspeaker in various conventional mountings.



sions in terms of the loudspeaker constant and the desired frequency characteristics. The application of these formulæ, however, demands a complete knowledge of the conditions under which they were being used, otherwise the results can be laughable. In acoustics all sorts of nasty things happen; resistance varies with frequency (but only sometimes) and component values vary with the weather. One is almost tempted to suggest that guesswork would yield as good results.

Fortunately this is not quite true, and in order to simplify the design of enclosures for their various loudspeaker systems Goodmans Industries have worked out the optimum enclosure volume for each system and have designed and marketed for each system a panel containing the acoustic components corresponding to R_f and M in the foregoing analogies. These panels are slightly inaccurately known as acoustic resistance units or ARUs but in fact the required mass component is also included so that all the home constructor needs to do is to make a box of the prescribed internal volume and cut two holes, one for the loudspeaker and one for the appropriate ARU, and having lined the enclosure and screwed these items into place, the enclosure will exhibit all the properties originally stated. The manufacturers have produced this unit, since they feel that in view of the foregoing discussions it is not possible to offer any simple formulæ or design that could be used by persons not familiar with this type of work to produce the required acoustic components with any degree of accuracy.

The performance of Axiom enclosures has been compared with that of other types. Listening tests have shown that the bass radiation is somewhat better than that from the reflex type cabinet at middle bass frequencies and considerably better at the low frequencies, thereby imparting a warm, well-balanced quality to the reproduction. Tests with an oscillator showed that a strong, pure 20-c/s fundamental note could be radiated without excessive cone movement. Transient curves taken showed a very short decay time, characteristic of non-resonant conditions. This is the more interesting when one realizes that the volume of this type of enclosure is about half that of a correctly designed reflex cabinet for the same speaker.

In addition to the qualities mentioned this type of enclosure has the following advantages:—

(1) It is simple and cheap to construct.

(2) The dimensions of the enclosure (corresponding to C in the analogous circuit) are not extremely critical and may be varied up to ± 10%, if necessary for " styling."

(3) The enclosure can be of any shape and the acoustic resistance unit can be placed in any position relative to the speaker.

(4) The resonant frequency of the loudspeaker is not critical, although, if higher than the value for which the enclosure was designed, the bass extension will be reduced.

Theoretically the bass response of any enclosed loudspeaker will tend to fall, due to the damping applied to the cone reducing the condition of mass control. In the enclosure we have described, however, the impedance applied to the cone governs its velocity in a predetermined manner, thereby securing a higher efficiency, which in practice made bass boosting unnecessary, even when used in conjunction with loudspeakers having high electromagnetic damping.

This enclosure design has been named " Axiom " after the range of high-fidelity loudspeakers manufactured by Goodmans Industries. Patent applications have been made.

"Wireless World" Index

COPIES of the index to the material published in *Wireless World* during 1955 are now available from our Publishers, price 1s (postage 2½d). It includes both general and classified indexes. Cloth binding cases with index cost 7s 6d (postage 6d). The binding of readers' own issues can be undertaken by our Publishers, the cost per volume, including the index and binding case, being 22s 6d, plus 1s 6d postage on the bound volume.

LETTERS TO THE EDITOR

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

F.M. Receiver Design

I FIND the persistent advocacy and use of an i.f. of 10.7 Mc/s for f.m. receivers very disturbing. This i.f. is being used by all but one or two manufacturers in this country and has twice recently been used in designs appearing in your journal—in April and August of last year.

I am beginning to wonder whether there is some mysticism attached to the figure 10.7. This particular frequency was chosen by the designers of the ratio detector who published details of the detector transformer design in the *R.C.A. Review* of June, 1947. This was over eight years ago and in a different continent. I submit that this frequency is totally unsuited to our needs in 1955. I hesitate to suggest that the reason for its adoption in this country is laziness, but with the advances in valves and techniques since 1947, is there any other excuse?

With the oscillator operating above the signal frequency the main danger is oscillator harmonic radiation on television channels 9 to 12. With the oscillator below the signal frequency the interference possibilities are oscillator harmonic radiation on channel 6 and second-channel interference from television channel 5. In both cases fundamental oscillator radiation can take place within the signal-frequency band. In view of this, I am amazed to learn that a recent recommendation from a manufacturer's organization—who should know better—supports the general adoption of 10.7 Mc/s as the i.f. for f.m. receivers, with the oscillator operating below the signal frequency. This is only postponing the evil day until television channel 6 is in use and v.h.f. broadcasting arrives in S. Wales and Newcastle. If ever the remaining 95-100 Mc/s of Band II are released for broadcasting, the fun will wax fast and furious.

These dangers were more than adequately expressed by the Editor of your sister journal *Wireless Engineer* in February of last year and I feel that *Wireless World* could, and should, do more to warn the industry of the dangers of persisting with this unsuitable frequency. There is far too much of the cloak and dagger attitude about these manufacturers' organizations—practically every piece of paper is marked "confidential." There is nothing confidential about this subject and it will be all the better for an airing in the columns of the technical press—and what better medium than *Wireless World?*

London, N.W.5. G. H. RUSSELL.

Channels for Trawlers

I REFER to a letter written by R. I. T. Falkner in the October issue of *Wireless World.*

V.H.F. for marine use is not the only part of the frequency spectrum which seems to be a muddle. What of the lower frequencies in the R/T bands (intership frequencies for fishing vessels) and the unfair allocations of frequencies to coasters and the armed forces? Whereas there are some 1,500 fishing vessels (big trawlers and small wooden motor fishing vessels) fitted with R/T to work on three intership frequencies, there are only 500 coasters to work on three channels of their own. The fishing industry, the largest commercial user, has been left out in the cold and never consulted as to its requirements.

Such technical considerations as keeping larger fishing vessels with larger aerials on a frequency of their own were never even given a thought.

Eighteen months ago the fishing industry asked for this matter to be put right and requested an allocation for small ships because of aerial limitations, but we have had no action.

This is typical of the attitude of the G.P.O., and Mr. Falkner bears this out by the f.m. *versus* a.m. "fracas." However, two wrongs do not make a right, and I do not think it within the scope of the Government or the G.P.O. to put this matter right. Until the interested parties are represented, including R.I.C., Shipping Chamber of Commerce, the fishing industry, mobile users of v.h.f., aircraft industry, radio amateurs and all interested users of radio channels form a British Communications Commission, we can do nothing.

Another scandal is the vast allocation to the armed forces of frequencies which are never used. Surely this is an unnecessary waste of frequencies when government stations can tell any British station to move from the frequency it (the government station) requires.

If a B.C.C. were formed we should make our own bed, and maybe the ether would be a happier place to live in because everyone would know what was going on and the G.P.O. would become only an operating company and a licence fee collector. Until a B.C.C. is formed, Mr. Falkner and myself are just voices from outer space expressing an opinion into a G.P.O.-created muddle of radio waves.

Radio Engineer, R. COLLINS,
The Great Grimsby Coal, Salt and Tanning Company.

Non-Standard Valves

I HAD hoped that the ghost of the non-standard Octal had by the passage of time been laid for ever. Alas, no. In building a pulsing unit recently my dealer in error sold me a valve socket of this type which I wired in. The result: a broken valve, a lot of wiring and a waste of time which I could ill spare.

If all the curses which have been heaped on the "Master-mind" which evolved this abomination were laid end to end they would surely stretch from here to perdition.

Esher, Surrey. E. F. WOODS.

"Q Measurement"

MAY I be permitted to point out that the error in my article noted by K. W. Stanley and E. Spielberg (your January issue) did not occur in my MS?

Secondly, may I comment on the alternative method as detailed by Messrs. Stanley and Spielberg? The expression for C_2, as given by them involves the value of C_1, the variable capacitor in the Q-meter, which either assumes correct calibration of this capacitor or involves indirect measurement of its capacity. However, as stated in the last-but-one sentence of my article, the method proposed by me does not entail accuracy of calibration of the Q-meter capacitor.

Southend-on-Sea, Essex. S. KANNAN.

Radio in Schools

MAY I take this opportunity of thanking you for publishing our appeal for radio equipment in your October issue and those of your readers who answered the appeal.

The response has been quite magnificent and has enabled us to make a successful beginning with our project. A. W. ROWE,
Headmaster, Holmer Green County School,
High Wycombe, Bucks.

F.M. for B.F.N.

NOVEL SYSTEM OF RADIO RELAYING: AUTOMATIC OPERATION

By J. D. PARKER, B.Sc. (Hons.)

On January 1st the medium-wave stations of the British Forces Network in Germany closed down and a network of nine v.h.f. stations took over. Some of the features of this f.m. network are outlined by the author who was until recently on the Control Commission in Germany as controller of radio

THE British Forces Network in Germany relied until recently on six medium-wave stations to provide coverage of that part of the Federal Republic that used to be called the British Zone of Occupation; i.e., the Northern and Western part of Germany. With one exception the stations were synchronized on 1214 kc/s, the same frequency as is used for the B.B.C. Light Programme. The network was synchronized, too, with the B.B.C. in order to minimize mutual interference and, since the indirect ray from the British Forces Network could give rise to a strong field strength in the U.K. and vice-versa after sunset, it was necessary outside of daylight hours for the two networks to radiate the same programme. This meant that only for a comparatively short period in the middle of the day could the Forces Network generate its own programme to cover local news and items of specific interest to the Serviceman in the British Zone of Germany.

As a result, however, of experience gained with one or two pilot f.m. transmitters set up in areas of particularly bad medium-wave reception, it was decided in 1954 to operate in Band II. The network finally chosen, which was brought into service on January 1st, comprises nine stations. (See Table 1.) The location of eight of these and the estimated coverage are shown in the map on page 82.

This frequency-modulated network has several interesting features.

1. The transmitters are entirely automatic in operation, each one being equipped with a spare 250-W drive stage and a control unit which decides in case of breakdown which is the best way to combine the units still working to give the maximum output.

2. The system is so arranged that, apart from the cables linking the Cologne studios to the two main stations, Bonn and Langenberg, and that between Hanover and Berlin, all stations are linked by radio (see Fig. 1). The system used is known in Germany as *Ballempfang* and amounts to a radio relay using the intermediate transmitters as broadcasting stations. This has not only important financial advantages, but frees the system from the limitation of quality imposed by lines.

3. The stations at Langenberg, Nordhelle, Herford, Hanover and Verden do not use conventional drive stages, such as are used in a normal frequency-modulation transmitter, but virtually act as high-power frequency changers. For example, the Herford station picks up the programme from Nordhelle (89.15 Mc/s) or Langenberg (89.10 Mc/s) and after frequency conversion re-radiates it with an effective power of 15 kW on a new frequency (96.6 Mc/s).

4. The transmitter at Herford, an important link in the chain because of its geographical position, is further secured against breakdown by the provision of two complete automatic transmitters. In addition

TABLE I

Station	E.R.P. (kW)	Frequency (Mc/s)
Bonn...	2	96.55
Langenberg	60	89.10
Nordhelle	15	89.15
Herford	15	96.60
Hanover	15	89.40
Verden	60	90.30
Pinneberg (Hamburg) ...	15	98.40
Drachenberg	24	99.30
Berlin	8	87.60

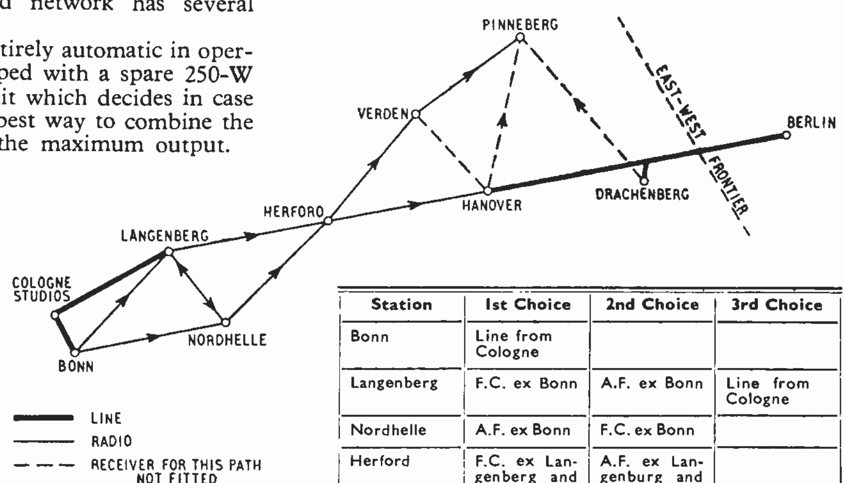


Fig. 1. As shown here diagrammatically, most of the transmitters are both broadcasting and relay stations.

Station	1st Choice	2nd Choice	3rd Choice
Bonn	Line from Cologne		
Langenberg	F.C. ex Bonn	A.F. ex Bonn	Line from Cologne
Nordhelle	A.F. ex Bonn	F.C. ex Bonn	
Herford	F.C. ex Langenberg and Nordhelle	A.F. ex Langenburg and Nordhelle	
Hanover	F.C. ex Herford	A.F. ex Herford	
Verden	F.C. ex Herford	A.F. ex Herford	A.F. ex Hanover
Pinneberg	F.C. ex Verden	A.F. ex Verden	

F.C. = Frequency Changer Transmitter. A.F. = Audio Frequency fed to Drive Stage.

an extra receiver is provided so as to give a second choice of feeder station, *viz* Nordhelle, should Langenberg, which is the normal feeder station, break down.

Transmitter Features

Basically the transmitters consist of a 250-W drive stage, or alternatively a 250-W frequency-changer drive stage, with amplifiers appropriate to the rated power output.

Each 250-watt drive unit contains a regenerative oscillator on $\frac{1}{8}$th of the final frequency of the transmitter, which is frequency modulated by a reactance valve push-pull modulator. The audio-frequency voltage input to the transmitter is amplified in the a.f. amplifier and pre-emphasized before being fed to the modulator by a network whose time-constant can be either 50 or 75 μsec.

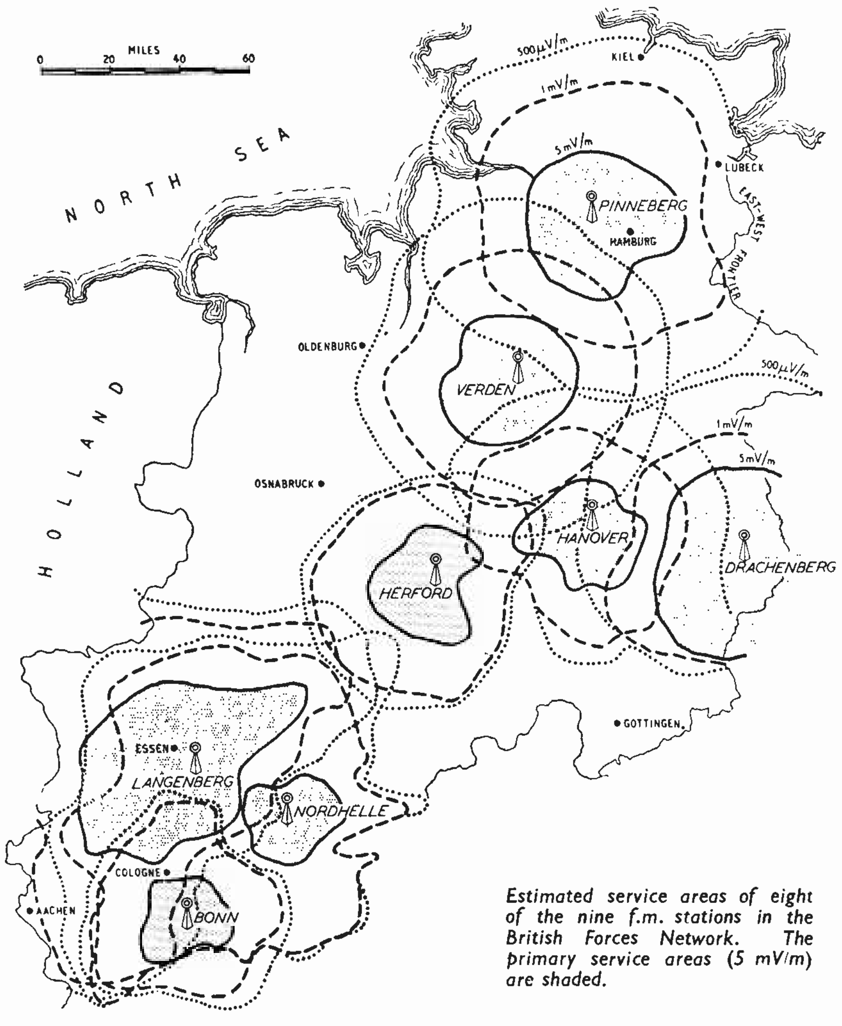
The oscillator frequency is multplied in a 3-stage radio-frequency amplifier, the output power of which is 8 watts. This output is fed to an amplifier where the frequency is doubled once more and the power brought up to 250 W. An automatic frequency control is used to keep the carrier frequency steady. It consists of a crystal-controlled oscillator which is compared with the frequency of the exciter. For comparison, use is made of a low-pass filter which in this case converts frequency variations to amplitude variations. The voltages ahead of and after the low-pass filter are applied to the windings of a polarized relay. The armature of this relay remains in its central position for a predetermined difference frequency. If this difference frequency changes, the relay armature moves to one side or the other and starts a motor running in one direction or the other, this in turn retunes the exciter until the predetermined frequency difference is reached. Thus the exciter is maintained at a constant difference frequency with reference to the crystal oscillator, the magnitude of the difference frequency being fixed by the circuit design. By this means frequency deviations of the transmitter are limited to $\pm 1{,}000$ c/s. The exciter is fed by an electronically regulated power supply that maintains a high-tension voltage accurate to 0.1 per cent over the possible range of mains supply voltages. This ensures very good stability of the exciter oscillator and consequently only occasional correction by the automatic frequency control.

The 250-W frequency changer drive unit, which is used at each station where modulation is supplied by means of a radio relay, is of particular interest. This unit replaces a normal drive stage which has to be fed by the a.f. output from a receiver. In operation the programme from one station is received by the next station in the network and after appropriate frequency conversion and power amplification is re-radiated.

The frequency conversion circuit comprises a receiver, which is in principle a superheterodyne with an additional stage through which a portion of the oscillator voltage is tapped off and also an arrangement whereby a portion of the i.f. voltage is tapped off ahead of the last limiter stage.

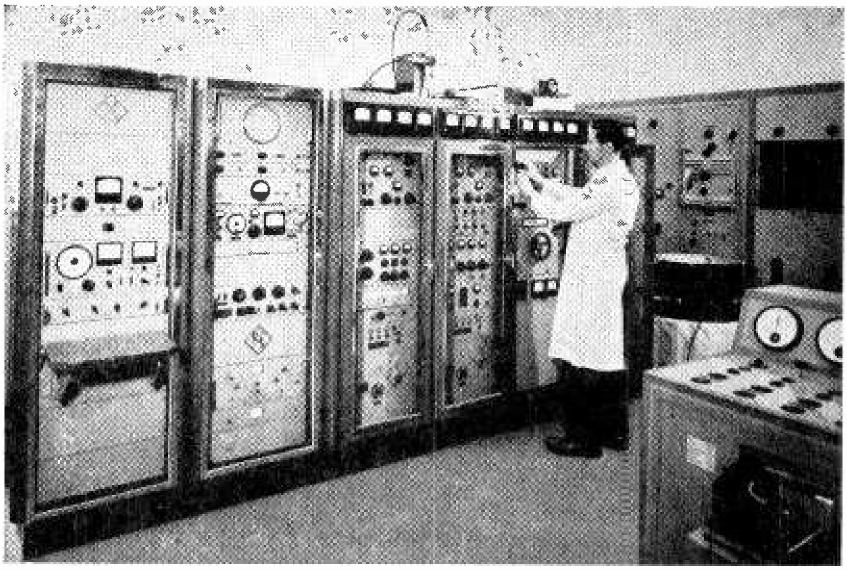
Both of these voltages are passed to a convertor unit where the conversion of the received frequency into the transmitted frequency is performed. The convertor unit consists of a crystal-controlled oscillator working at a frequency equal to the difference between the received and transmitted frequencies, a mixer stage, a buffer amplifier, a second mixer stage and a further radio-frequency pre-amplifier.

The voltage tapped off from the receiver variable



Estimated service areas of eight of the nine f.m. stations in the British Forces Network. The primary service areas (5 mV/m) are shaded.

frequency oscillator is applied both to the mixer stage of the receiver and to the first mixer of the convertor unit. By mixing with the frequency of the crystal-controlled difference oscillator, a frequency is produced which, after selective amplification to eliminate spurious signals developed in the mixing process, is passed to the second mixer stage. In this stage it beats with the frequency tapped off from the i.f. amplifier and produces at the output of the mixer stage a frequency different from the received frequency by the frequency of the difference oscillator, i.e., the required transmitting frequency. This final transmitting frequency voltage is fed to the pre-amplifier which rejects unwanted image frequencies and provides sufficient drive power for the subsequent 250-W amplifier.



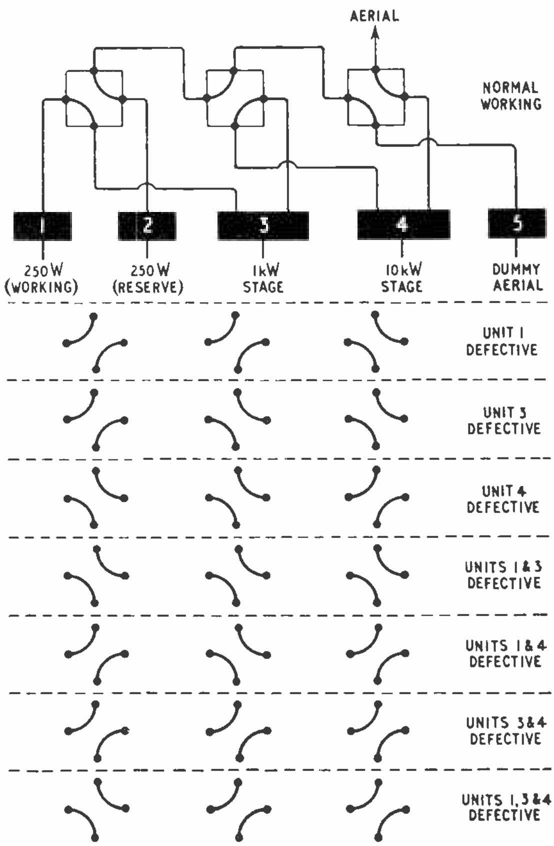
Installation at Pinneberg which is typical of that at the other stations in the network.

The basic principle of the automatic switching system is that a spare 250-W drive unit is provided, and in the event of a failure the control unit automatically couples the remaining working units so as to give the nearest approach to the rated output. If a unit fails the necessary switching operations never take more than one minute. Fig. 2 shows the possible combinations that may be set up. Thus by appropriate positioning of the three basic switches, no matter which units are defective, the maximum possible power can be fed to the aerial. In the meantime the defective stage or stages are automatically coupled to the dummy aerial ready for testing when the maintenance staff arrives.

Any failure of the 250-watt frequency conversion drive stage, or of the station being received, counts as a failure of the drive stage and brings in the reserve drive stage of the normal type with its associated receiver pre-tuned to another station. In practice the incidence of failure from automatic transmitters using interstage switching and one "passive" reserve drive stage is very low.

It is anticipated that with the introduction of v.h.f. there will be a considerable financial economy for not only are the running costs lower but the rental of landlines—costing some £20,000 a year—is largely obviated.

Fig. 2. Possible combinations in the automatic switching system in the event of failure of one or more units.



Frequency Allocation Problems

One aspect of the setting up of the network not mentioned so far is that of frequency allocation. When planning for B.F.N. it was necessary to ensure that a minimum frequency separation of 0.9 Mc/s between receive and transmit frequencies was maintained. In this connection, it has to be remembered that if the frequency separation is only of this small order, the voltage impressed on the receiver must not exceed 0.2 V.

The aerials used for the radio relay reception are Yagi types, used either singly or double depending on the field strength at the receiving point. For efficient working of the receiver section of the frequency-changer unit it was decided to standardize on an input signal level of 100 μV which gives a signal-to-noise ratio of better than 70 dB for 100% modulation.

At most stations the B.F.N. transmitter is on the same site as the N.W.D.R. transmitter so that the aerial is used for radiating at least two, and more generally, three programmes on different frequencies. Also some of the aerials already installed at the stations do not cover the whole band 87.5-100 Mc/s. This imposed a further limitation on frequency planning.

In order to permit the German broadcasting organization to use an additional frequency at Nordhelle the original B.F.N. frequency plan has been modified. Nordhelle and Langenberg now radiate on the same nominal frequency of 89.10 Mc/s but with the Nordhelle frequency offset by 50 kc/s. This system of operation provides attractive possibilities of frequency economy. A whole series of problems, however, had to be overcome, since in operating pairs of stations in this manner the phasing of the audio modulation has to be equalized. When the modulation is fed by line the setting up of the required time delay equalizing network is fairly straightforward. In this particular case, however, the modulation is supplied by radio relay and the distances from the parent station at Bonn to Langenberg on the one hand, and Nordhelle on the other are respectively 67.2 km and 72 km, making a time difference of 16 microseconds. The distances to the next station, Herford, are from Langenberg 136.5 km and from Nordhelle 126.0 km, i.e., a difference of 10.5 km giving a time difference of 35 microseconds. Thus the path from Bonn to Herford is 51 μsec longer *via* Langenberg than *via* Nordhelle. In order to achieve phase equality at Herford a time delay must be put into the Nordhelle chain. The Langenberg transmitter under normal operating conditions is operated as a frequency-changer transmitter, thus giving no appreciable delay due to transmitter circuits, whilst the Nordhelle transmitter is operated with a normal drive stage fed by audio obtained by de-modulating the signal from Bonn. This leads to a delay of about 20 μsec, necessitating the addition of a further 30 μsec delay in the Bonn-Nordhelle-Herford path. This delay is obtained by the use of low-pass filter sections having a cut frequency of 21 kc/s. Tests were made at Herford of the distortion factors at 1,000 cycles and 5,000 cycles with and without the delay circuits with the following results:—

	1,000 cycles		5,000 cycles	
	2nd Harmonic Distortion (%)	3rd Harmonic Distortion (%)	2nd Harmonic Distortion (%)	3rd Harmonic Distortion (%)
Langenberg direct reception ...	0.26	0.08	0.43	0.25
Nordhelle direct reception ...	0.27	0.09	0.78	0.23
Simultaneous reception with 30 μsec delay at Nordhelle ...	0.08	0.07	0.90	0.20

It will thus be seen that this method of operation not only saves one transmitting frequency; i.e., that at Nordhelle, but also that the resultant distortion over the radio relay system is generally less than that obtained with the more orthodox system of operation.

Commercial Literature

Variable Voltage-Regulating Transformers. New "Variacs," including miniature types, a model with 3.5 kVA rating and a series giving increased output current, listed in an illustrated catalogue from Claude Lyons, Valley Works, Ware Road, Hoddesdon, Herts.

Waveguide Bench for mounting microwave instruments, consisting of horizontal chromium-plated bars, in three-foot lengths, with vertical pillars (for supporting instruments) which can be slid along and adjusted in height. Leaflet from Elliott Brothers (London), Century Works, Lewisham, London, S.E.13.

Sensitive D.C. Voltmeter, using reflecting galvanometer, with resistance of 1 MΩ per volt. Ten ranges from 0.01 V full-scale to 300 V full-scale. Response time 2 seconds. Power supply from mains or battery. Leaflet from W. G. Pye and Co., "Granta" Works, Newmarket Road, Cambridge.

Television Aerial Adaptor, for adapting Band-I aerials to Band-III reception. Consists of extra element clamped to lower element of Band-I dipole immediately below the insulator, with optional director in front. Leaflet and technical data from The Meadow-Dale Manufacturing Company, The Dale, Willenhall, Staffs.

Siting of Band-III Aerials for good reception. Advice to dealers, with examples showing what action to take under various conditions when poor pictures are obtained. Leaflet from Bush Radio, Power Road, Chiswick, London, W.4.

Nickel-Cadmium Accumulators, 1.25-volt, made by Deutsche Edison-Akkumulatoren Company and notable for being permanently sealed and requiring no maintenance. Disc-type cells of 60-150 mAh capacity, cylindrical types of 125 mAh and above, and rectangular types of 1.7-20 Ah. Details in a leaflet from the British concessionaires, G. A. Stanley Palmer, Maxwell House, Arundel Street, Strand, London, W.C.2.

Corner Loudspeaker with exponential bass horn and unusual horn-loading system for giving uniform dispersion of mid and high frequencies. Natural resonance below 10 c/s, power rating 6 watts, gap flux 21,000-22,000 gauss. Leaflet from The Lowther Manufacturing Company, St. Marks Road, Bromley, Kent. Also a leaflet on other drive units.

Valve Voltmeter for measuring extremely small a.f. voltages. Maximum gain is 110 dB, corresponding to f.s.d. for 31.6 μV, and can be varied in steps of 10 dB. Also a microphone amplifier, 20 c/s-20 kc/s, and a filter set, containing 27 third-octave filters for standardized main frequencies, designed to work in conjunction with it. All are new Brüel and Kjær instruments, described on leaflets from B and K Laboratories, 59-61, Union Street, London, S.E.1.

Band-III Fringe Aerial consisting of two 4-element Yagi units spaced by $\frac{3}{4}$ wavelength. Narrow acceptance angle for high noise rejection and designed for coverage of Channels 7, 8 and 9. Two models available, one with mast and the other for fixing to existing mast. Leaflet from Labgear (Cambridge), Willow Place, Cambridge.

Voltage Coincidence Oscilloscope

By R. J. D. REEVES*

Multi-channel Displays on a Single-beam Cathode-ray Tube

AN unusual method of presenting waveforms on the face of a cathode-ray tube is suggested, in which a conventional time base is used but the Y deflection is independent of the input. The raster is brightened at appropriate instants and the resultant collection of dots can be made to represent the input wave-shape. Time-base speed is limited, but multi-channel presentation can be achieved with vertical expansion and accurate voltage measurement on all channels.

IN most applications of the cathode-ray oscilloscope a repetitive function, which is available as a voltage waveform, is displayed on the tube to provide facilities for time and amplitude measurements of that waveform. Since the electron beam in the measuring tube is usually deflected by voltage it is natural to apply the function directly to the deflector plates; if necessary through the medium of a voltage amplifier. Although the limitations associated with this technique can hardly be described as severe, some difficulties are encountered when extremely high or extremely low frequencies require amplification; or when the function has a comparatively high d.c. content which is required to be measured, and which in any case calls for substantial "shift" to bring the waveform variations to the linear part of the transfer characteristic.

Voltage amplification is, however, not the only available means of portraying a waveform on the tube, and it may well be that alternatives to the classical approach will show advantages in certain applications.

It will be appreciated that an event occupying the bounded space on the c.r.t. screen represents a function which is being continuously repeated in the time domain, this point being tacitly understood by the observer, who is not directly aware of the periodic nature of the display.

But in a conventional oscillograph the luminous image itself is being retraced at the same rate and frequency (or a principal sub-harmonic), not because it is important to do so but simply because it is expedient. Discounting the possibility of highly mobile displays, it may be said that the information content of the waveform is exhausted after the first sweep, and thereafter the problem is one of recording the display. Yet the amplifier is capable of transferring new information in every sweep, and therefore it may be asserted that, fundamentally, it is of unnecessarily high quality for its ultimate purpose. It is only necessary to retrace the display sufficiently often to avoid flicker and to indicate a change in the waveform without undue delay. It is not important to trace at the speed of occurrence of the event and it is not even necessary to trace in the direction on the tube face which represents the elapse of time.

This discrepancy between the speed of the event and the necessary speed of image synthesis can be exploited to make some improvement in the presentation, as exemplified by modern "stroboscopic" methods, or, in the manner to be described here, to permit a more primitive technique to be applied to the problem of mapping the voltage-time function.

The proposed system substitutes a voltage-coincidence circuit for the customary Y amplifier and for this reason an instrument of this type is classified as a voltage-coincidence oscilloscope (v.c.o.). Both the method and the resulting image have apparent limitations, but these do not in general coincide with those of conventional voltage amplifiers and there are certain fields of application for which it is well adapted.

Voltage Coincidence Method. A normal time base circuit is required for the X deflection; the province of the voltage-coincidence method being entirely that of the Y and Z (brightening) co-ordinates. The schematic diagram is shown in Fig. 1.

A sinusoidal audio-frequency oscillator is allowed to run independently of the trigger or input waveforms so that its frequency is not correlated with

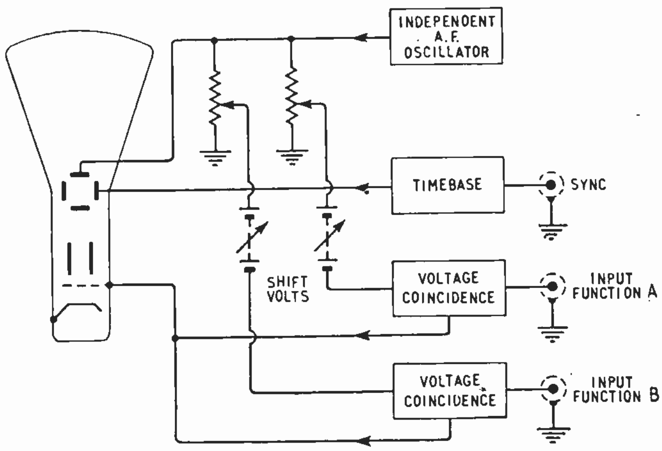


Fig. 1. Arrangement of circuit elements in the voltage-coincidence oscilloscope.

* E. K. Cole, Ltd.

that of the function to be presented. This oscillator provides a number of co-phased outputs, one of which is connected to the Y plates of the tube and deflects it fully. The others are reference signals which can be individually adjusted in magnitude and shifted in origin so that they explore a suitable part of the voltage scale. Between the waveforms to be examined and one of these reference signals is interposed a voltage coincidence circuit, which provides a brightening pulse for the tube whenever the two signals are at the same potential. In this way the time of the voltage coincidence is recorded as a dot on the sinusoidal trace, and the aggregate of such dots plots the shape of the input function.

On the faster time base speeds the number of coincidences obtained per scan may be few (see Fig. 2) but the point is that they can be accumulated over many scans, particularly if a long-persistence screen is used, for the dots do not in general fall in the same place on successive scans if the a.f. oscillator is running free. In fact, the time taken to synthesize the picture, i.e., accumulate sufficient dots, does not progressively shorten as the time base speed increases, but remains at a certain minimum value which is a function of the oscillator frequency and the screen afterglow time.

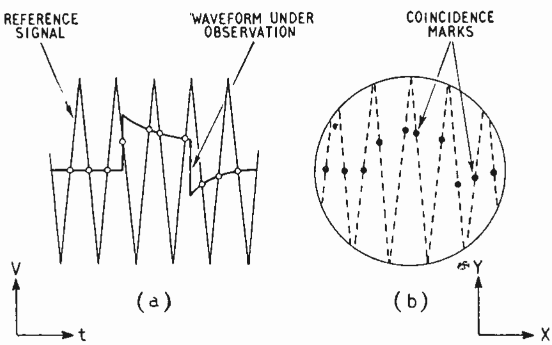
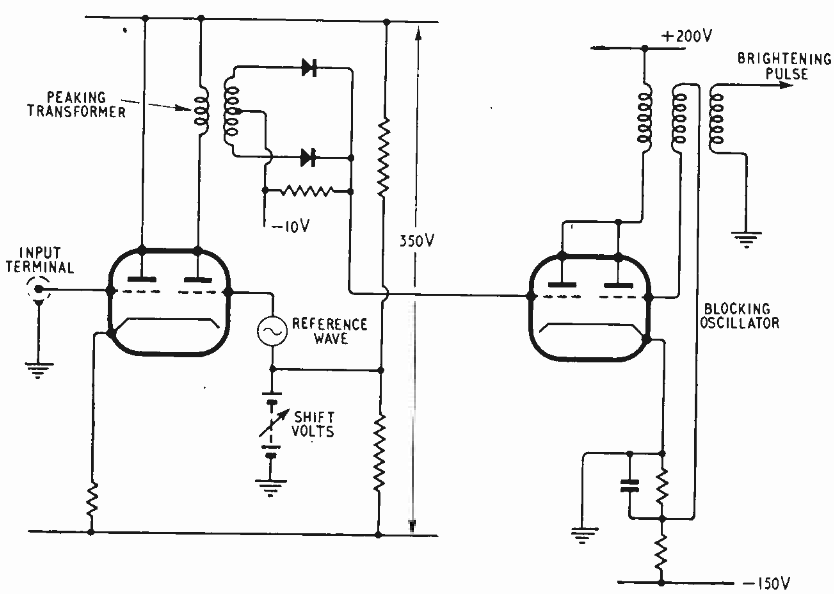


Fig. 2. (a) Graphical presentation of information in the voltage-time domain, (b) Resultant display on the c.r.t. screen.

Fig. 3. Basic coincidence circuit for one channel.



Other input waveforms can be compared with different reference signals and be presented at the same time, giving the effect of a multiply split beam. Each waveform can be individually shifted and magnified so that functions that are widelv separated on the voltage scale may be brought into juxtaposition on the screen. If a common reference signal is used with all input waveforms the voltage aperture that the screen represents is guaranteed to be uniform, and signal magnitudes may be compared, or voltage cursor lines may be superposed on one function. Furthermore, a monitored cursor line may be shifted across the function to measure it when the reference voltage is common to both.

The amplitude of the reference wave defines the apparent screen aperture and therefore corresponds to the normal sensitivity control, and the maximum sensitivity is limited by the resolution of the voltage coincidence circuit. The available shift is of course quite unrelated to the sensitivity and a vertical expansion effect can be achieved. For this feature the power supply for the input stage of the coincidence circuit should preferably be carried on the shift volts, in order to reduce the necessary signal-handling capacity of that stage. This permits shift potentials extending to several hundred volts to be freely employed.

Because the Y-deflection waveform is so elementary it is preferable to drive the "stiffest" tube co-ordinate with this signal and use the more sensitive plates for the time-base deflection. In this way the time base indirectly benefits from this type of presentation.

The coincidence circuits should be of high input impedance, and a "long tailed pair" circuit is suitable at the front end. An elementary circuit for one channel is shown in Fig. 3. The brightening pulses from any number of channels can be combined through buffer diodes at the c.r.t. grid.

Fig. 4 is a photograph of a two channel presentation, taken on a Mazda 30 C2 cathode-ray tube with a P2 (long afterglow) screen using a reference wave with a frequency of approximately 1 kc/s and a 2 msec time scale. The exposure was 1/10th second.

Limitations of the Method. The factor which limits the permissible speed of the time base is the duration of the brightening pulse, for this is intended to mark a point and should therefore occupy, say, less than one-five-hundredth part of the sweep duration. A 100-μsec sweep therefore demands 0.2 μsec pulses and represents about the ultimate limit of time base speed. The method is therefore not suited for fast displays.

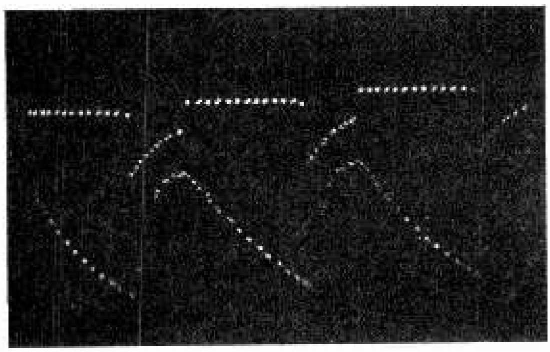


Fig. 4. Simultaneous display of two waveforms, using separate coincidence channels.

Another point is that the trace is plainly discontinuous in appearance, with the collection of discrete points much in evidence. The effect is of a travelling chain of dots, constrained to follow the shape of the input function, but unfortunately the chain never appears to have sufficient velocity to create the impression of complete continuity.

A more serious consequence of the dot structure is that false patterns can be suggested when the time base is incorrectly synchronized to the waveform. The multiple-valued patterns produced on a conventional oscillograph when the time base frequency has a fractional relation to that of the input waveform is a familiar occurrence. Under similar conditions the v.c.o. will sometimes produce a pattern which suggests a single-valued function of erroneous shape. Such false patterns can be shifted or destroyed by slightly changing the oscillator frequency, and this constitutes a test for the validity of the display.

The problems encountered in the design of this kind of instrument are quite different to the familiar ones of amplification, and are largely concerned with the method of indicating voltage coincidence. The coincidence circuit is required to resolve small voltage differences and yet accept large voltage swings without drawing current, and at the same time it is desirable to maintain simplicity in this part of the circuit because the input stage at least has to be duplicated for each separate input channel. A fixed time lag in registering the coincidence is no drawback because it can be allowed for by advancing the phase of the sine wave which sweeps the tube, relative to the reference signals. The display in Fig. 4 shows a slight dispersion of the dots due to an uncompensated time lag.

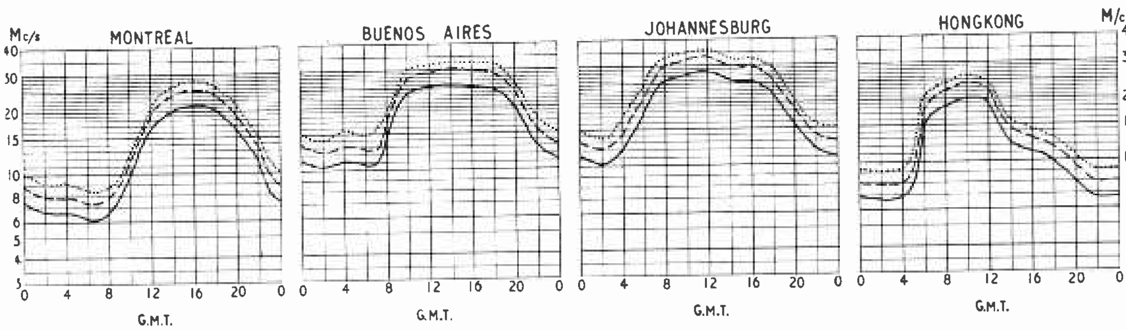
The image on the screen does not suffer from any distortion in the usual sense although the unwanted dot structure may become objectionable or inadequate in cases where the duty cycle of the time base is very low or the frequency of the a.f. oscillator has an unfortunate relationship to that of the time base. The last condition can be cured, of course, by having an adjustment control for the oscillator frequency. The fact that the Y-deflection signal is in d.c. isolation from all inputs ensures that there is no difficulty with astigmatism, and this, coupled with the fact that the brightness of the trace is independent of the input waveform, means that the brightness and focus controls are certainly only occasionally required, and may perhaps be pre-set.

The facilities for voltage measurement are good, for the shift volts are not constrained by the sensitivity setting, and the waveform can be very accurately lined up with a cursor. Moreover, since all channels are direct coupled, several known voltage cursors can be displayed at once.

We may conclude, therefore, that the v.c.o. can be used as an advanced form of valve voltmeter for composite displays of d.c. potentials and waveforms in the audio-frequency range. But the point to be emphasized here is that this is a new technique which is worth consideration not only for the possibility of a new item of test equipment, but whenever d.c. presentation is called for in specialized equipment.[1]

[1] R. J. D. Reeves. "Klystron Control System." To be published in *Wireless Engineer*.

SHORT-WAVE CONDITIONS *Predictions for February*



.... 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

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 February.

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

Distribution Systems

RELAYING SOUND AND TELEVISION IN BLOCKS OF FLATS

*By J. KASON**

SOME criticism has lately appeared in the press and technical journals of the ever increasing number of aerials adorning our towns and giving a distant community the appearance of a Picasso sketch. As new television programmes come into operation the multiplicity of aerials will become prohibitive. The owners of blocks of flats and/or local authorities object to the erection of individual aerials. The answer to that is relay distribution within the building. This is already very popular in the U.S.A.[1], and is growing in this country. Many suitable systems have been in existence for some time, and one, using channel amplifiers, has been specifically developed to provide programme relay services comprising television, f.m. sound and all-wave radio for blocks of flats.

There are three basic ways of distributing television signals, (*i*) low frequency carrier transmission, (*ii*) conversion of signals in Band III into available channels in Band I, and (*iii*) distribution of information at transmitted frequencies.

With the first mentioned system the carriers may have frequencies of say 5.4 Mc/s and 2.7 Mc/s with video and sound modulation by Band I and Band III signals. At the receiving end, 5-valve terminal units would receive the signals satisfactorily. The low-carrier distribution method can also be adapted for reception with ordinary television receivers. The advantage of such a system is the centralization of all equipment, the small number of repeaters required due to the low loss in the cable at this low carrier frequency and the higher power handling capabilities of the output valve or valves since better cross modulation figures are achievable at these frequencies.

The second system entails conversion of signals in Band III into available channels in Band I. Some distribution systems based on this type of conversion are in use to-day, and have the advantage that cable losses are halved, compared with what they would be at Band III frequencies. They have, however, some disadvantages *viz*:—a maximum of no more than two or three television channels can be accommodated because only four unused channels are available and receiver selectivity prevents the use of adjacent channels. It is difficult to design a cheap and efficient three-channel filter in Band I. Not all television receivers to-day, even those with turret tuners, have all the channels available for reception. The receivers would, in neighbouring flats in some cases, tend to interact with each other, and with f.m. receivers.

The third system of distribution of signals at transmitted frequencies can be accomplished in one of two ways, *i.e.*, by using distributed amplifiers or channel amplifiers.

In the first method of the third system a combination of channel amplifiers and distributed[2,3] amplifiers is used for the distribution of signals. The mixing of bands is done at low level to avoid cross modulation. Low gain channel amplifiers are used to equalize the levels of various programmes in such a way as to compensate for line losses (output $\propto \sqrt{f}$). The combined signals are then fed *via* distributed amplifiers and splitters into lines. This system has the following advantages:—

The added reliability of the distributed amplifiers, since a failure (but not a breakdown) in the operation of one valve due to ageing reduces the gain by only 1.6dB (6 valve stage using EF95). There is no appreciable response characteristic drift. Higher output is permissible for a given cross modulation figure, since the total power output is shared by several valves, and theoretically and closely in practice the relationship between power and the number of valves is linear, hence this is an economical system when high power is required.

The disadvantages are:—low gain for a given number of valves. Critical impedance matching is required. The possible cumulative build up in frequency errors when

* E.M.I. Sales and Service.

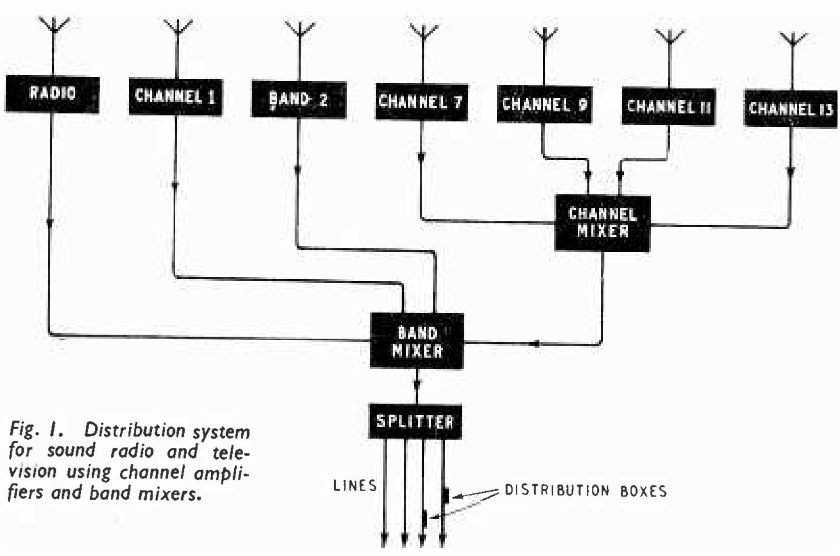
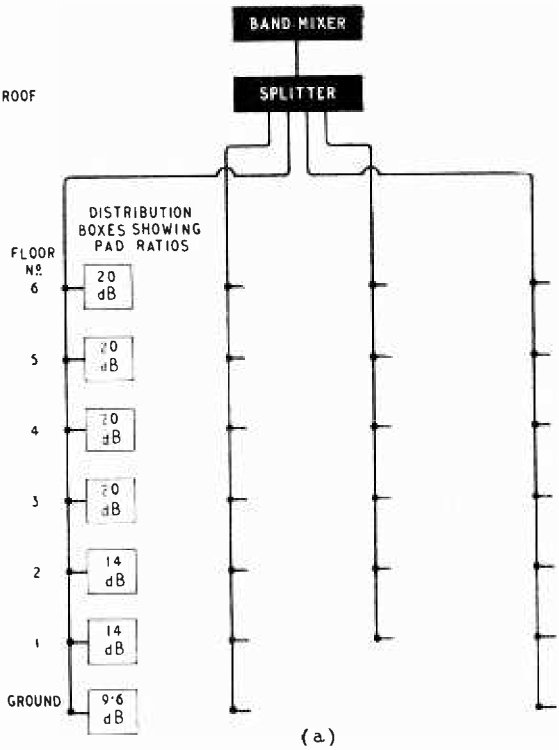


Fig. 1. Distribution system for sound radio and television using channel amplifiers and band mixers.



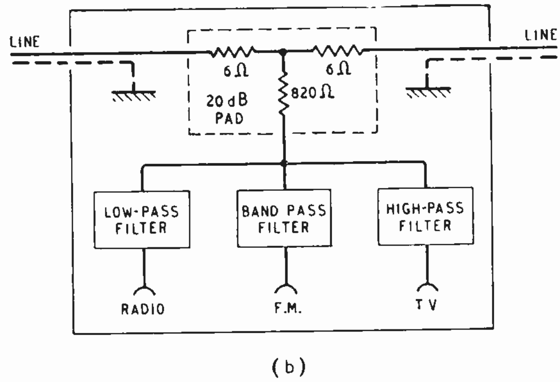


Fig. 2. (a) Schematic distribution system network for a small block of flats; (b) details of 20-dB pad.

amplifiers are cascaded. Valve failure, other than that due to ageing, puts all channels out of action.

In the second method channel amplifiers are employed for the distribution of signals. This system is easy to maintain and manufacture, shows a high gain per valve, low noise and low cost. Moreover, there is no need for channel equalizers, and on failure, only one channel is put out of service (Fig. 1). Although for a given cross modulation the output is relatively low, it is sufficient to feed television programmes throughout a block of flats. Examining the last two methods of distribution, it is evident that for installation in flats where the number of outlet points seldom exceeds one hundred, the channel transmission method is the most economical. The latter part of this article therefore deals with the channel method of distribution.

A schematic diagram of a block of flats is shown in Fig. 2. The network is planned on the basis of a maximum loss of 46 dB and the provision of 1 mV at the viewer's television outlet socket. This loss includes the insertion losses of the coaxial semi-air spaced 100-ohm lines, splitters, distribution boxes, band mixers and channel mixers. The planning of networks of various blocks of flats has shown that a 200-mV output into 100-ohm distribution lines is sufficient on Band III. A design of some equipment has been based on the above assumption and the following section of this article will deal with some aspects of this design.

One particular channel amplifier used for distribution of Band-III programmes employs Z152 valves with 210 volts supply for anodes and screens, and the maximum possible output with acceptable cross modulation is 250 mV fed into a 100-ohm coaxial cable. This amplifier has a gain of 52 dB in any channel in Band III with a bandwidth of 4 Mc/s (at ± 1 dB). Because of variation of signal strength in various localities, it has been found necessary to provide a gain control fitted in the cathode of the first Z152 valve with a maximum range of 20 dB. Over-coupled circuits are used for the inter-valve couplings and, with all trimmers tuned to the centre frequency of any channel in Band III, a bandwidth of 4 Mc/s is obtained.

Tests of this amplifier yielded very satisfactory results but only the noise and cross modulation tests need be discussed here, since these show the essential limitation in the performance of the amplifier. A signal of 300 μV fed into the Channel-9 amplifier showed a negligible increase of noise. However, for fringe areas, a cascode pre-amplifier is available. No noticeable cross modulation could be seen on a television receiver at the end of a 100-ohm line when the channel amplifier was providing 200 mV input. The cross modulation is 55 dB or better for the above output with the gain control in any position.

In order to find the isolation factor required for the band mixing unit (Fig. 1, 2, 3) a Band-III amplifier was tested for inter-modulation with an interfering Band-I signal, both amplifiers working at full output. The test showed that additional isolation of more than 10 dB had to be provided by the filters. Not more however than 1 dB of insertion loss can be permitted for Band III, as 200 mV output is only just sufficient to feed a 500-ft line satisfactorily.

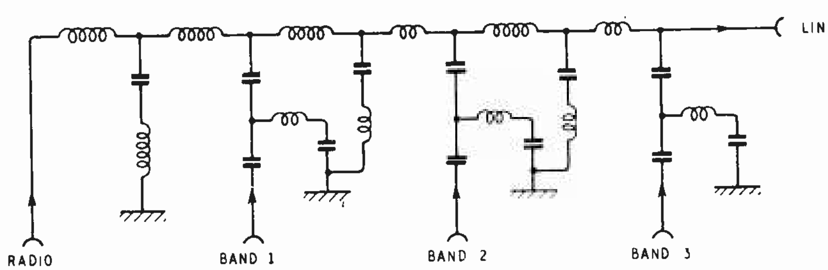


Fig. 3. Circuit arrangement of a band mixing unit.

Maximally flat, 4*th* order filters were chosen for the band mixing unit and proved to work satisfactorily. Some results obtained with these filters are given in the table.

For the purpose of combining several Band-III programmes, a two-channel mixing unit[4] based on resonant lines has been developed. Coaxial lines having an effective magnification, or " Q " factor, of approximately 30 were used and gave an insertion loss of under 0.8 dB on Channels 9 and 11 for negligible cross modulation at full output. A similar channel mixer has been developed for three or four channels in Band III. In the case of the three-channel mixing unit, Channels 7, 9 and 11 were used and Channel 13 was added for the four-channel mixer. Purely arbitrary channel frequencies were chosen to prove the design, and the insertion loss for any type of mixer remained under 0.85 dB.

Distribution boxes[5] providing for all-wave radio, Band I, Band II and Band III have been developed. Second order, lumped constant, filters were used as band acceptors and rejectors. Fig. 2 (b) shows a distribution box incorporating a 20-dB pad, which steps down the line voltage to a level of approximately 1 mV. The series arms (6 ohms) of the pad restore the cable impedance (Z_0). High-voltage-level signals are used in distribution because the effect of pick up by the cable is minimized and the high pad ratios prevent any appreciable interaction between the terminal units in flats. The filters isolate the receivers connected to the distribution box.

A splitter unit is a symmetrical resistive network giving, for n ways, $\frac{1}{n}$ th of the supplied voltage at the output terminals in such a way that the image and characteristic impedances are maintained. A four-way splitter is shown in Fig. 4.

The value of each resistance is given by

$$r = Z_0 \frac{n-1}{n+1}$$

where r = resistance
Z_0 = characteristic impedance
n = number of ways.

Conclusion:—The laboratory tests showed that the channel type of distribution is satisfactory for blocks of flats. The system is simple with regard to manufacture and maintenance, and very flexible. A further increase of one channel in Band III needs only the addition of one amplifier to the network. A Band-II amplifier of 15-Mc/s bandwidth and its auxiliary equipment have also been developed, but are only mentioned in passing (Fig. 1) in this article.

Field tests were carried out in a number of blocks of flats in London on lead type coaxial cables and braided paper insulated lines with favourable results.

Comparing the two methods of the third system, distribution by means of distributed amplifiers is advantageous where a high power is required, while the channel method is more economical for small installations.

FILTER TABLE

Frequency Mc/s	Insertion Loss dB	Atten in Bands dB		Atten in Bands dB
200	0.9	B II 13.8		B I 29.8
94	1.8	B I 25.1		B III 25.1
55	0.9	B II 20.3		B III 19.3
		Attenuation (dB) in Bands		
		I	II	III
25	0.5	22	23	25
5	1.0	25	31	33

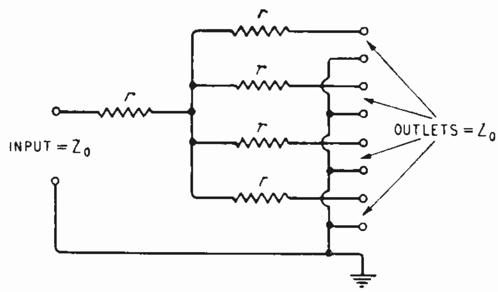


Fig. 4. Basic circuit for a splitter unit.

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[2] W. S. Percival (E.M.I.) British Patent No. 460562, 1953.
[3] " Distributed Amplifiers." B. Murphy, *Wireless Engineer*, February 1953.
[4] J. Kason & A. E. Lander (E.M.I.) British Patent Application No. 27135/55.
[5] J. Kason (E.M.I.) British Patent Application No. 27279/55.

LONG-DISTANCE I.T.A. RECEPTION

HOWEVER unpredictable the I.T.A. television signal may be in its own London area, it is still apparently capable of propagating to places far beyond the normal service area. One such place is Bristol, over 100 miles from the Croydon transmitter. From here B. L. Morley has written to say that he has been getting consistently good reception ever since the service began, except for a period of five days when severe fading was experienced. The picture quality has apparently been good, and on the test card the 2.5-Mc/s bars have been clearly defined.

Mr. Morley has been viewing on several different receivers and they have all been normal commercial types, though it has been necessary to use an r.f. pre-amplifier as well on some occasions. The aerial is also a commercially available product, but is somewhat more elaborate than the usual sort of domestic array. It consists of four units, each containing five elements, arranged side by side and mounted on a 26-ft mast on a chimney stack, giving an overall height of about 50ft. The receiving point itself is some 380ft above sea level. Quite good results have also been obtained with an aerial using just two of the five-element units. The feeder is a semi-air-spaced low-loss type.

Band-III convertors have not been very successful under these conditions, however, and a considerable amount of interference has been experienced with them. On one occasion the interference was identified as being from radio taxis operating in central London!

As a further proof of the propagating abilities of the 200-Mc/s signal, Mr. Morley mentions that he has also obtained a picture from the 1-kW I.T.A. test transmitter at Lichfield, which is over 90 miles away.

LOOPS WITHIN LOOPS

By "CATHODE RAY"

LIGHT ON THE MORE COMPLICATED FEEDBACK SYSTEMS — POSITIVE AS WELL AS NEGATIVE

IT may be that so much talk about feedback has, by an association of ideas, made everybody heartily sick. But the fact is that this "loops within loops" aspect of the subject is the one I actually set out to expound, and the last two months' instalments have been merely introductory. However, let no one who has missed them think he has made the mistake of coming in at the last stage of a close-knit serial. The only necessary qualification for reading on is an understanding of ordinary simple feedback systems.

In these, a connection is taken from somewhere near what might rather pompously be termed the "point of utilization" of the amplifier to some point nearer the input. Thus there is formed a complete loop. The loop is made to embrace as much of the amplifier as practicable, and especially those parts nearest the output end, for two reasons: (1) to extend the distortion-reducing benefits of feedback to as much of the system as possible and especially to those parts where most distortion is created; and (2) because these benefits are proportional to the amount of amplification round the loop. The most important parts to include are the output stage and output transformer, because they cannot be designed in any other way for really low distortion without restricting them to an uneconomically low power output. But if even the whole secondary voltage of the output transformer were fed back to the input of the same stage, it would be too little to do much good. So even if distortion in the preceding stage or stages were small enough not to bother about, there would still be a good reason for including it or them in the loop.

Unfortunately, however, the farther back the feedback is taken, the greater the total phase shift around the loop at extreme frequencies and the greater the likelihood of oscillation at such frequencies. Efforts to prevent this have resulted in a flood of ingenious devices and expedients, some of them very difficult for non-specialists to follow. But for amplifiers that are meant to have really low distortion, these difficulties must not be allowed to stand in the way. Feedback over at least two and probably three stages can almost be taken as a necessity.

A typical arrangement is outlined in Fig. 1. The first valve is designed to give a high voltage amplification; the next is a phase splitter to provide the two anti-phase signals for the push-pull output stage; and feedback is taken from the transformer secondary to the cathode of the first valve of this group. The designer's intention may have been a single-loop feedback system, but whether he wanted it or not there is a feedback loop within the main loop—V_2 has 50% feedback as a result of half the total output load resistance being on the cathode side. Here there is of course no possibility of bypassing this cathode resistor to get rid of the local feedback. But some amplifier circuits enclose within the main feedback loop a valve that would normally have its bias resistor bypassed, and one may wonder whether or not to do it. Perhaps one decides to leave it unbypassed, with the thrifty idea of saving a capacitor and at the same time throwing in a little extra feedback—all to the good, surely! Is this reasoning sound? Again, sometimes there is unintentional feedback at very low frequencies because of the power-supply impedance being common to all valves and not sufficiently short-circuited by the smoothing capacitor. Intentional or not, how does one calculate feedback when there are one or more loops within or overlapping the main loop?

Perhaps it will be a good idea to work up to answering this general question by way of a particular example. One of the simplest and most likely has already been mentioned—how does omitting a cathode resistor bypass capacitor within a feedback loop affect the general situation? Does it make its own little contribution to reducing distortion, or what? Fig. 2 shows the circuit, with the omitted capacitor dotted. There is no reason why this stage should not be considered on its own, for if one were

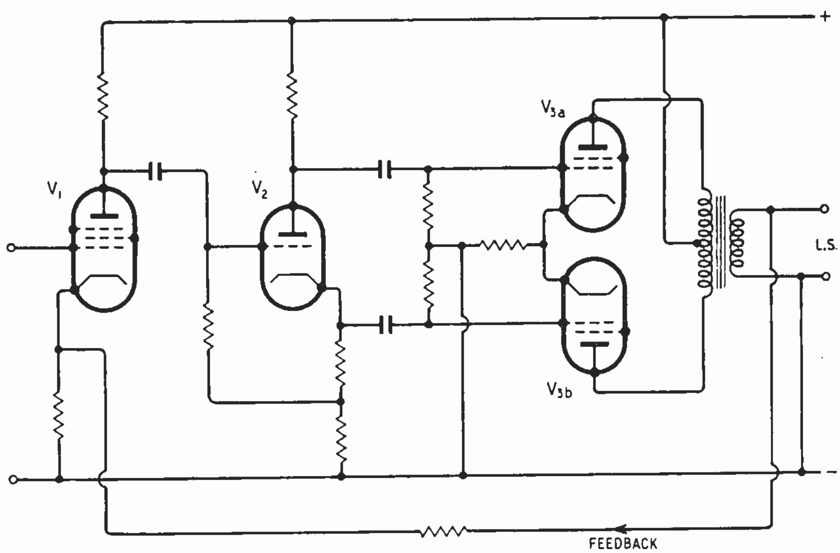


Fig. 1. Example of a typical audio amplifier circuit, with a deliberately provided negative feedback loop, and also an unintentional internal loop caused by cathode feedback in the middle (phase splitter) stage. How does this affect the whole performance of the amplifier?

shut up in a box with it one would have no means of telling whether there was an all-embracing feedback loop in the great world outside, or not. The voltages set up by the signal current flowing through R_k oppose the incoming signal voltages, leaving less to reach the valve between cathode and grid. I am not going to stop to quote the formulæ for calculating the effects precisely—they are in the reference books. As one would expect, these effects are the same as one gets in a cathode follower—amplification, distortion and phase-shift all reduced—but much less so, because R_k is only a small part of the resistance in series with the valve.

It is unlikely that there will be very great need for reducing distortion in a stage like this, but every little helps. Reduction of phase shift is likely to be still more welcome to the people outside, who know that this valve does form part of a multi-stage feedback loop. As for the loss of amplification, isn't that always the price?

Misguided Local Enterprise

If now we imagine ourselves outside the box, not knowing exactly what is in it, and examining the other stages and the feedback connection, we will be unable to tell whether the box contains its own little feedback system as shown, or a valve in which the lower gain, phase shift, etc., are obtained without feedback—by using a lower coupling resistance, say.

In other words, the whole system can be reduced (at least on paper, and conceivably in actuality) to one having only a single feedback loop. That really contains the essence of the answer to the general question about how to calculate multi-loop feedback systems.

As we judged, the slight reduction of distortion within the Fig. 2 stage is good so far as it goes, and the reduced phase shift is even more encouraging for the system outside that stage. But we may perhaps not have remembered that the reduction of distortion in that whole system brought about by the main feedback is proportional to the amplification (or gain) round the main loop, and if the gain falls in one stage it falls in that proportion throughout, and distortion rises in the same proportion. Nearly all the total distortion is likely to be due to the output stage, so even if the whole of the distortion in the Fig. 2 stage were completely eliminated by its own little private feedback system (which of course it wouldn't be) that could not nearly make up for the rise in total distortion resulting from the reduced efficiency of the main feedback system. It is like a well-meaning employee starting a scheme that is a success in his own department but seriously upsets the working of the firm as a whole.

Having absorbed this perhaps rather unexpected outcome of our inquiry, we may be better prepared to accept the idea of deliberately introducing *positive* feedback into a negative-feedback amplifier. This idea was expounded by Thomas Roddam in the July 1950 issue, but for the sake of any who don't go back that far I will say what you may have already guessed by the process of reversing everything we found for negative feedback—that introducing positive feedback within the main loop increases the loop gain and therefore reduces the total distortion; and, provided that the stage whose gain is increased by the positive feedback originally had little distortion, the increase of distortion within that stage will do little to offset the overall reduction. The figures he gave as an example of this were 10% distortion in the output stage and 1% in the two preceding stages; total without feedback between 10% and 11%. Applying 20 dB of positive feedback to the two stages raises their distortion to 10%, making a total that at the worst might be 20%; but 40 dB of main-loop negative feedback reduces this to 0.2% or less. Removing the internal positive feedback reduces the negative feedback to 20 dB, with the result that the total distortion is about 1%.

But with positive feedback the amplifier will presumably be more difficult to keep from oscillating, not only because of the increased loop gain, but also because of the increase in phase shift. So, as T. Roddam emphasized, this is not a method to try unless one is well able to cope with the stability problem.

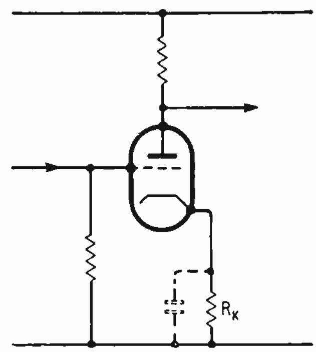


Fig. 2. Often one has to decide whether or not to use a cathode-resistor bypass (shown dotted). Which is better?

One idea, which seemed very clever when it occurred to me, is to arrange the positive feedback system so that its phase shifts right round and makes it negative just at those frequencies where the negative feedback is threatening trouble by becoming positive. Whenever a clever idea occurs to me I can be sure that (1) there is a snag in it, or (2) it has been thought of before. In this case a possible snag seemed to be that at frequencies where each kind of feedback contributed about 90° phase shift, the loop gain might not be far short of maximum and the conditions for oscillation therefore fulfilled. However, at least some people who thought of it before seem to have made it work to their satisfaction. An amplifier of this kind, due to J. M. Miller of U.S.A., was described in *Audio Engineering* for December 1953 (p.2). How does it avoid the supposed snag?

Positive Feedback

If we find ourselves getting a bit confused at this stage it may be because our Nyquist diagrams, showing how feedback that starts by being negative can swing right over at certain frequencies to become positive, may have given us the impression that we already know all about positive feedback. For instance, some readers may happen to remember that last month I said that even when negative feedback becomes positive it still reduces phase shift. When they read this month that positive feedback *increases* phase shift they may conclude that I at least am getting sufficiently confused to contradict myself. Perhaps we had better look into positive feedback a little more carefully.

Fig. 3(a) shows the upper-frequency part of a Nyquist diagram for a negative feedback amplifier. The net input voltage, assumed to be one unit strong, is represented by the vector *ei*. The fed-back voltage at medium frequencies is represented by ef_m, exactly 180° away and therefore purely negative. As the frequency rises, this vector turns clockwise (representing phase lag) and gets shorter (representing falling amplification). If these effects happen to be caused by shunt capacitance in two stages, the vector ef_t at frequency f_t—the "turning frequency," at which the capacitive reactances are equal to the resistances they shunt—lags 90° (ϕ_t) and is half ef_m in length. The total input needed with feedback has been altered from $f_m i$ to $f_t i$. Assuming that the fed-back voltage is in phase with the output voltage, then the phase shift with feedback is ϕ'_t, which is obviously much less than ϕ_t. Even at a much higher frequency, f_h, the phase shift ϕ'_h with feedback is less than ϕ_h without, although we are now within the positive-feedback zone—a circle with centre i and radius ie. This phase-reducing effect holds good right up to the frequency f_p at which both angles are 180° and feedback therefore purely positive.

But—and this is the important point—when feedback is *meant* to be positive one doesn't reckon phase angles in the same way. Our diagram (a) has been drawn for 4 : 1 negative feedback (=12 dB), represented by ef_m being 4 times as long as ei. So it reduces the gain of the amplifier five-fold ($f_m i$ is 5 times as long as ei). Suppose for the sake of comparison that f_p is four-fifths of the way along ei. Then at that frequency the feedback *increases* the gain five-fold. Suppose now that we intentionally apply this amount of positive feedback. Then at the frequency f_m the picture must be the same as at f_p with negative feedback—f_m must be plotted where f_p was. Fig. 3(b) shows that part of the diagram on an enlarged scale for clearness. The fed-back voltage ef_m is *in* phase with the net input ei at the normal working frequency f_m, and the total input with feedback, $f_m i$, is comparatively small, and is also at 0°.

At a slightly raised frequency f_r, at which the fed-back and output voltages lag the net input by the angle ϕ_r, the angle between them and the total input (which is now $f_r i$) is ϕ'_r. Positive feedback has considerably increased the phase shift. What is more, the total input has been increased several-fold, from $f_m i$ to $f_r i$, which means that the loss of amplification when positive feedback is used is much worse than with no feedback and of course worse still than with negative feedback. All this is obvious even with the quite small feedback ratio I have chosen in order not to crowd the diagrams, but if you draw one with f_m very close to i, to represent a really strong dose of positive feedback, you will see how even a small ϕ_r causes a large ϕ'_r and a rapid increase in the required input voltage.

So if we now widen ϕ_r out into a full right angle, the phase shift of the stage as a whole (ϕ'_r) widens out into rather more than a right angle. But not enough, when added to ϕ'_t in Fig. 3(a) to make two right angles (180°). It would be at a rather higher frequency that the inclusion of the positive-feedback stage (b) in the loop represented by (a) would swing the negative-feedback vector through 180°, and it is clear that at that frequency the five-fold gain of the positive-feedback stage would have turned into a substantial loss, to be added to the loss in the rest of the main (negative-feedback) loop. The greater the reliance on positive feedback for gain at f_m, the greater the fall off at the extreme frequencies at which the total phase-shift is 180°, and therefore the greater the negative feedback and consequent distortion-cancellation that could be adopted without oscillation.

Another thing: if a lot of positive feedback is used internally, the overall gain needed for effective feedback can be obtained with fewer stages and therefore less rapid phase-shift with frequency.

So internal positive feedback looks like a good thing. Yet some authorities, such as W. T. Duerdoth, advocate internal *negative* feedback. Is there any end to the contradictions in this subject? Well, one apparent contradiction has just been cleared up. What, then, about conflicting advice about the kind of feedback to use in internal loops?

A Box of Tricks

It is true that the greater the loop gain (represented by the length of ef_m in Fig. 3(a) in a main negative feedback system, the greater the reduction of distortion in the amplifier included in that loop; and internal positive feedback is one way if increasing the loop gain. So it does look as if internal negative feedback, by reducing the loop gain, would result in less reduction of distortion and would therefore be a bad thing. But there are more ways of increasing loop gain than by increasing the amplification of one or more of the stages. Loop gain is what we have been denoting in previous articles by AB. Just now we have been concentrating on A—the gain of the amplifier. But what about B, the proportion of the output fed back? Generally it is much easier to avoid extreme-frequency phase shift in B than in A. So it is quite a reasonable policy to use internal negative feedback to reduce phase shift, and then make up the loss in A—or perhaps more than make it up—by increasing B.

There are still some tricks left in the box. We have

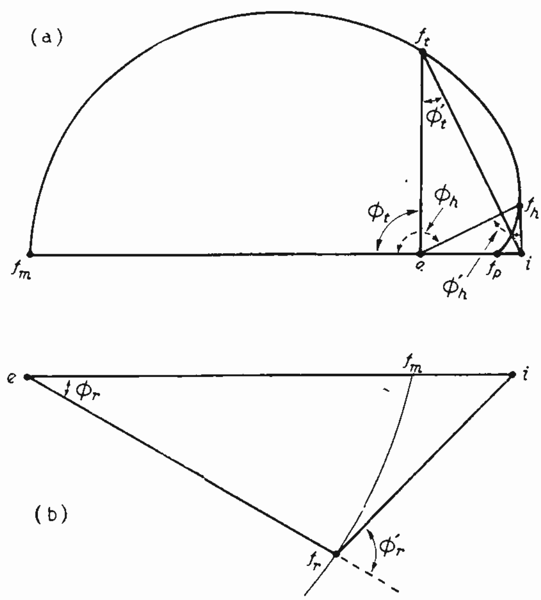


Fig. 3. If this Nyquist diagram referred to a circuit containing two shunt capacitances, its turning frequency (f_t) would be at 90° from f_m as shown. but at 180° it would have curved in to e. Here it is assumed that some complication keeps the loop gain up to ef_p. In (a), feedback at working frequencies (f_m) is negative, in (b), positive

been assuming that internal negative feedback, of which Fig. 2 is a sweetly simple specimen, would reduce gain (and so reduce overall negative feedback) over the working range of frequencies, and then tend to restore the gain at extreme frequencies (as a result of stray capacitances, etc.). Except that this restoration is pushed to such extreme frequencies that the gain in the rest of the amplifier has a chance by then of being reduced to safe limits, it looks as if this policy achieves the worst everywhere. But as long ago as 1938* L. I. Farren described a subsidiary (or internal) feedback in which this objection was met. Instead of a plain resistance R_k he specified a combination of impedances, R_1, R_2, C and L in Fig. 4. The idea was to minimize negative feedback in the working frequency band, so that almost the full stage gain is developed there, and to cut down the stage gain by negative feedback at the extreme frequencies where there is risk of oscillation.

The Brink of the Pit

I have just been reading in the French radio journal *Toute la Radio* an entertaining and not discouraging review of the collection of my works published under the title "Second Thoughts on Radio Theory." In France there are two popular books called "La Radio?—Mais c'est trés simple" and "La Television?—mais c'est trés simple," and the reviewer says he would have liked to have written "Second Thoughts" himself because he would have been able to entitle it "La Radio?—Mais ce *n'est pas* si simple!" He seems to have got the idea that "ce diable d'homme" (as his co-reviewer called me) is wont to take the simplest concepts in our science, reveal that they are in reality very complicated and then, just as the reader is falling into the grip of gloom and despondency, re-establish order and clarity.

Well, I hadn't thought of it that way, but it does rather look as if it is how the present study is going.

*"Some Properties of Negative Feedback Amplifiers," *Wireles Engineer*, Jan. 1938. pp. 25-35.

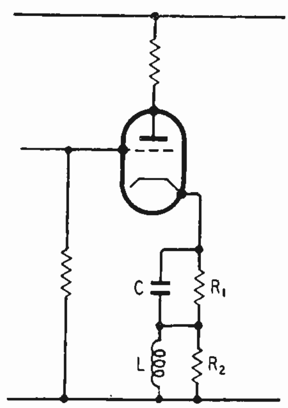
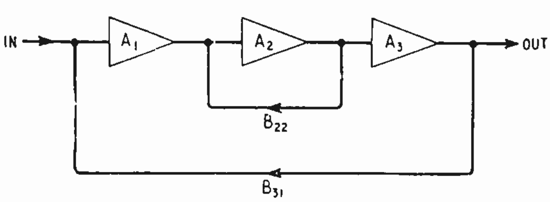


Fig. 4. Cathode network designed to minimize negative feedback at working frequencies and bring it into effect at extreme frequencies.

Below: Fig. 5. Three-stage amplifier with a main feedback loop (A_1 A_2 A_3 B_{31}) and an internal loop (A_2 B_{22}).



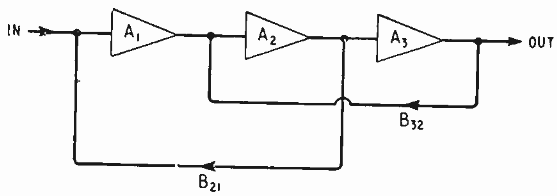


Fig. 6. Three-stage amplifier with overlapping feedback loops.

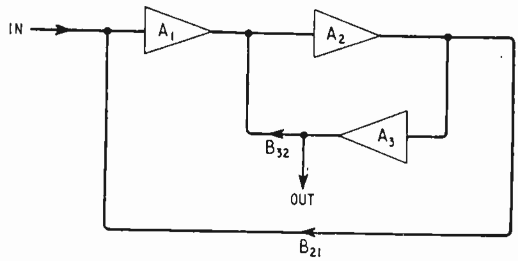


Fig. 7. This is the same system as in Fig. 6, but drawn so as to make it easier to see how the same rule as in Fig. 5 can be applied.

Feedback is a very simple idea. But I should imagine that any readers who hadn't proceeded beyond that view of it are by now convinced that it is an exceedingly complicated and tricky subject, full of apparent contradictions and practical difficulties. If any are not so convinced, I would assure them that we have hardly begun. We might go on to consider in detail how the Fig. 4 system influences for good and ill the design of the amplifier of which it forms a part, and what decides the component values. Then (if that seemed too easy) we could go on to some much trickier circuits that have been used. So far we have said nothing about how the various feedback loops are connected up; one finds that our convenient assumption that they don't interact with one another except forward through the amplifier doesn't necessarily hold. This particular problem of interconnection is further complicated by another effect of feedback that we have left out of account—its raising and lowering of input and output impedances. As I pointed out in the June 1955 issue in connection with cathode followers, in some systems the amount of feedback that operates depends greatly on the impedance of the signal source.

Lest the grip of gloom and despondency, alluded to above, become permanent, I will hasten to say that we are not going to do any of these things. Some brave souls among us may be prepared to venture into the jaws of death and perhaps return bearing with them a lucrative trade in hi-fi equipment; let me not deter them. But I have a responsibility toward the others, and for their sake will conclude with a simple outline of how loops within loops can be reckoned.

The guiding principle is one that we came across near the start; namely, substituting equivalent feedbackless stages for those that have local feedback. It is necessary, of course, to confine this simple treatment to systems in which the feedback connections don't affect stages outside their loop except as a result of what they do inside. Fig. 5 shows an amplifier consisting of three single stages, represented by the conventional symbol. (Personally I think the triangular amplifier symbol would be more telling if it widened in the direction in which the signals were magnified; but that is by the way.) As hitherto, A denotes voltage magnification without feedback, and A′ is the same with feedback. The two are related by the basic feedback formula

$$A' = \frac{A}{1 - AB}$$

All that follows is just filling in the details. B is the proportion of A fed back, and in Fig. 5 two loops are shown to demonstrate the notation: " B_{31} " means B from the output of stage 3 to the input of 1, and so on.

The total gain of all three stages without any feedback (= A) is of course found by multiplying all the separate stage gains together:

$$A = A_1 A_2 A_3$$

Suppose now that B_{22} is connected. Then A_2 becomes A'_2, which of course is $A_2/(1 - A_2B_{22})$. Consequently the total gain becomes $A_1 A'_2 A_3$. One can then tackle the amplifier as a whole with B_{31} connected:

$$A' = \frac{A_1 A'_2 A_3}{1 - A_1 A'_2 A_3 B_{31}}$$

If you substitute $A_2/(1 - A_2 B_{22})$ for A'_2 and then multiply above and below by $1 - A_2 B_{22}$ you will get

$$A' = \frac{A_1 A_2 A_3}{1 - A_2B_{22} - A_1 A_2 A_3 B_{31}} = \frac{A}{1 - (A_2B_{22} + AB_{31})}$$

This is interesting, because it shows that A′ can be found in one go by using the basic formula, modified by interpreting AB as the sum of the separate loop gains. If the inside loop had been around A_1 or A_3, then $A_1 B_{11}$ or $A_3 B_{33}$ would have appeared instead of $A_2 B_{22}$. If it had been around A_1 *and* A_2, then the term would have been $A_1 A_2 B_{21}$.

The thing can perhaps be made clearer by choosing some numbers for Fig. 5. Suppose $A_1 = A_2 = A_3 = 10$, $B_{22} = -0.4$, and $B_{31} = -0.02$. Then A without feedback is 1,000. With B_{22} only, $A'_2 = 10/(1 + 4) = 2$. So $A_1 A'_2 A_3 = 200$. Applying B_{31} to this, $A' = 200/(1 + 4) = 40$. It could have been arrived at direct: $A' = 1000/(1 + 4 + 20) = 40$. If B_{22} were omitted, $A' = 1000/(1 + 20) = 47.6$. Incidentally, although B_{22} reduces this only slightly to 40, it increases distortion considerably, for that is divided by only 1 + 4 instead of 1 + 20.

Fig. 6 looks more tricky. But it sorts itself out if redrawn as in Fig. 7. Here the internal loop gain is $A_2 A_3 B_{32}$, and the same method as above can be applied to find $(A_1 A_2)'$:

$$(A_1 A_2)' = \frac{A_1 A_2}{1 - (A_1 A_2 B_{21} + A_2 A_3 B_{32})}$$

Between the output of A_2 and the output of A_3 there is the gain A_3, so A′ is the above multiplied by A_3:

$$A' = \frac{A}{1 - (A_1 A_2 B_{21} + A_2 A_3 B_{32})}$$

So Fig. 6 is covered by the same rule as Fig. 5.

At frequencies where the AB terms are either purely negative or positive, A′ can be calculated by simple arithmetic; but in general A and B are " complex " numbers, necessitating such methods as measuring vector diagrams or the use of *j*. So in practice, although the principle is simple enough, it can mean a bit of work.

A.F.C. Unit for F.M. Receivers

Correcting Frequency Drift in a Novel Manner : Adding a Tuning Indicator

By C. H. BANKS

INCORPORATING a reactance valve in an existing receiver for automatic frequency control is often a major operation, involving the re-design of the oscillator stage. The a.f.c. system described here obviates this difficulty combining simplicity with convenience and a high degree of efficiency. It also has the following advantages:

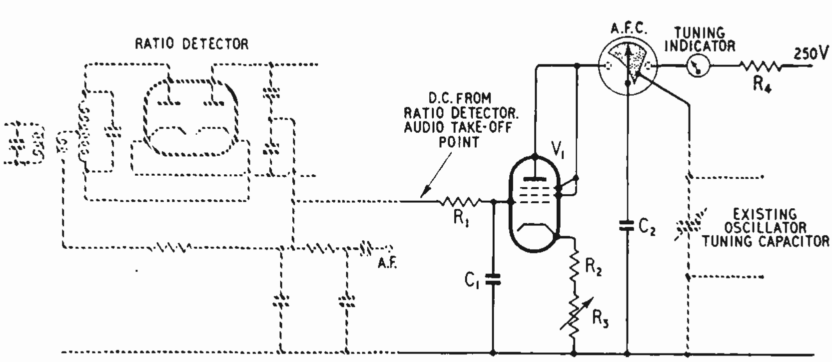
1. Asymmetrical control is easily obtained. As f.m. receivers invariably drift in one direction only almost the full range of control can be concentrated on correcting for this drift. Alternatively the control can be symmetrical.

2. No major alteration is required to an existing receiver and apart from the usual power supplies only one connection is made to the receiver's oscillator.

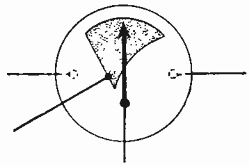
3. Only one valve (which can be placed anywhere convenient) is used; this performs the dual function of operating the indicator and the a.f.c. device.

The operation of the controlling unit (see Fig. 1 on page 96), can be more readily understood if the basic principles of motor-driven a.f.c. are borne in mind. The sequence is as follows: a discriminator and a d.c. amplifier drive a reversible motor, which is coupled to a small variable capacitor, and, which in turn, is shunted across the oscillator tuning capacitor. In the system described here a moving-coil meter movement is used as a motor; the needle then becomes a ready-made moving capacitor vane. All we have to supply is a slip of metal for a fixed vane, cut to the shape depicted in Fig. 1. It is mounted either in front or behind the pointer of the meter and as close to it as possible without actually touching and is connected by a short lead to the oscillator tuning capacitor.

An example of how the system works is as follows:—say the oscillator drifts to a lower frequency; the discriminator voltage, which is applied to the grid of V_1, swings negative. The resulting drop in anode current tends to move the needle to the left; the slightest movement however reduces the capacitance between the needle and the fixed vane, and therefore the total capacitance across the oscillator, thus increasing the oscillator frequency



Left: Fig. 1. Circuit arrangement of the a.f.c. system and tuning indicator described in the text.



Below: Fig. 2. Alternative position of fixed vane on a.f.c. meter.

LIST OF PARTS

R_1	1 MΩ	R_3	500 Ω	C_1	0.5 μF
R_2	600 Ω	R_4	22 kΩ	C_2	100 pF

1 meter 0-5 mA full-scale deflection for tuning indicator.
1 meter 0-5 mA f.s.d., less glass and scale, for a.f.c.

and correcting for the drift. If the drift is to a higher frequency the reverse action takes place.

Dependent on receiver design, drift to a lower frequency may cause positive instead of negative swing. In which case the fixed vane should be reversed to the position indicated in Fig. 2. The positive swing will then bring about the desired reduction of capacitance.

If a mistake is made and the fixed vane is fitted the wrong way round, it will immediately become obvious, because the drift will be greatly accentuated and the signal, if it is possible to tune it in at all, will rapidly fade away. In order to make the operation as clear as possible C_2 is shown connected to the meter needle. In practice it is best connected to the terminal which is common to the needle and one side of the moving coil in the meter.

The time constant of R_1C_1, plays an important part in the design and should be not less than 0.5 *sec*, otherwise uncontrollable needle flutter may result. The larger the capacitance of C_1 the slower will be the movement of the controlling needle when tuning. In brief, R_1C_1 do more than filter out the audio signal, they smooth out needle flutter also. The best all round combination was found to be 1 MΩ and 0.5 μF. This may be slightly on the slow side but enables one to tune rapidly through stations with no answering needle movement, which is quite an advantage. It does not affect the a.f.c. efficiency, when tuning in a normal fashion.

Precise constructional details cannot be given as so much depends on individual requirements and the design of the f.m. unit. Suffice it to record that on a certain unit that gives excellent results, but drifts badly, the a.f.c. meter was mounted under the chassis, which in this case was used on its side. The controlling needle then passed within ¾in of the tuning capacitor and required only a short support and connection to the fixed vane. If a difference of h.t. potential exists between the pointer and the fixed vane thin insulation should be provided as a safeguard.

The tuning indicator, which has been in use since the early days of Wrotham, has proved stable and reliable over long periods and needs little explanation as it follows the same movements as the a.f.c. needle. It provides a useful check on performance. With no signal, the standing current, conveniently set at half scale, is, of course, the correct tuning point. For the benefit of those who, like the author, do not appreciate the doubtful decorative qualities of meters in a domestic receiver it is only necessary to cut a small aperture in the control panel just large enough to show the relevant movement of the needle of the tuning indicator.

With V_1 grid earthed, alignment simply consists of setting the a.f.c. needle opposite that section of the fixed plate upon which it is desired to work, either by adjusting R_3 or by the meter zero adjustment. It should be central, as in Fig. 1, if symmetrical working is required; towards the high-capacitance end, if the oscillator drift is known to be to a lower frequency; and towards the low-capacitance end if the drift is towards the higher frequencies. The receiver is then tuned in correctly and the calibration adjusted if required. Removal of the earth on V_1 will bring the tuning indicator and a.f.c. into operation. If all is well, stations will be found to occupy a little more space on the tuning scale than formerly and tuning is, somewhat simplified.

Apart from the importance of the time constant of R_1C_1 already mentioned, there is considerable latitude in the choice of components; but as a guide a list of those actually used in the original unit are given. V_1 is an SP61 strapped as indicated. There is no reason why a normal triode should not be used providing it is worked well within its capabilities and preferably on the straight section of its curve.

RADIO MEN IN AVIATION

AS the safe and regular operation of civil aircraft becomes more and more dependent upon the efficiency of electronic ground installations, the demand for electronics engineers and technicians in the Ministry of Transport and Civil Aviation's telecommunication organization increases.

New entrant radio technicians must have a basic knowledge of radio fundamentals and some practical experience either in the Services or industry. After nine weeks at the Ministry's Training Establishment, they take up duty at one of the aerodromes or specialized units but return to the school at intervals to gain proficiency in the maintenance of the more complicated electronic navigational aids.

The qualifications and experience needed to become a telecommunications technical officer (grade III) are under review but at present the Ordinary National Certificate in electrical engineering (or the City and Guilds Certificates in telecommunications principles III and radio III) together with eight years' experience in an appropriate technical field are necessary.

Simplified "Wow" and "Flutter" Measurement

BY R. G. WICKER

Using an Audio Oscillator and an Oscilloscope to Check a Tape Recorder

ALTHOUGH specially designed test equipment is generally used for the measurement of "wow" and "flutter" in the factory development and production of tape and disc reproducers, it is possible to achieve accurate results with simple standard test equipment.

The method to be described requires a calibrated audio-frequency source and a cathode-ray oscilloscope, and was worked out in detail while awaiting the delivery of a tape recorder. Subsequently, it was pointed out to the author that the method is basically the same as that described by E. W. Berth-Jones (*Wireless World*, December, 1949), but as that issue is now out of print and the original article dealt primarily with gramophone turntable fluctuations, an account of the author's experiences with a tape machine may prove to be of value.

If, in a machine with separate recording and playback heads, a constant tone is fed to the recording head, several wavelengths of the tone will be established on the tape between the record and playback heads. The number of whole and partial wavelengths will depend on (1) the frequency of the tone, (2) the speed of the tape which, together with the frequency, determines the wavelength, and (3) the distance between the heads. If we include amplifiers to bring the amplitude to a suitable level for observation there will be some phase shift which must be accounted for.

Of the above (3) is a constant and (1) can be made constant, at least for short periods of time. The remaining factor, tape speed, should be constant, but it is in fact variations of this which we wish to measure, and these will show up as variations in the phase relationship between input and output waveforms.

Let us see how this works out in practice. The only equipment required is a frequency-calibrated audio source tunable from about 50 c/s to at least 5,000 c/s (purity of waveform being unimportant), and a cathode-ray tube with its power supplies. X and Y amplifiers are a help but not essential.

Suppose that we have a tape recorder working at $7\frac{1}{2}$in/sec under test. First, we must measure the distance between the record and playback head gaps as accurately as possible—any error here results in an error of the same magnitude in the result.

Let this distance on our hypothetical recorder be 2 inches. A tone of 75 c/s is fed in the record head and simultaneously to the X plates of the c.r.t. The wavelength on the tape will be 0.1in and there will be 20 wavelengths between the heads.

Fig. 2. Appearance of trace for phase difference increments of 90°. The centre circle corresponding to 90° or 270°.

The output from the playback head amplifier is fed to the Y plates of the c.r.t., Fig. 1. The usual 1-1 Lissajous pattern will appear on the screen and, if the phase shift through the amplifier(s) is 90° or 270° this will be a circle[1]—if, as is usual, the phase shift is anything but 90° or 270° a small change in frequency can be made until a circle is obtained.

This hypothetical tape recorder being bad as far as "wow" is concerned, the picture swings from a circle first to one diagonal then to the other (any "flutter" will show up as a rapid change in pattern), Fig. 2. What is happening is that as the tape slows down the wavelength is shortened so that $20\frac{1}{4}$ cycles are accommodated within the two heads, whereas where it speeds up, only $19\frac{3}{4}$ cycles appear on our 2in of tape. The speed has varied in the ratio of $\frac{1}{2}$ cycle to 20 cycles or 2.5% which, as we said, is pretty bad.

Now having corrected

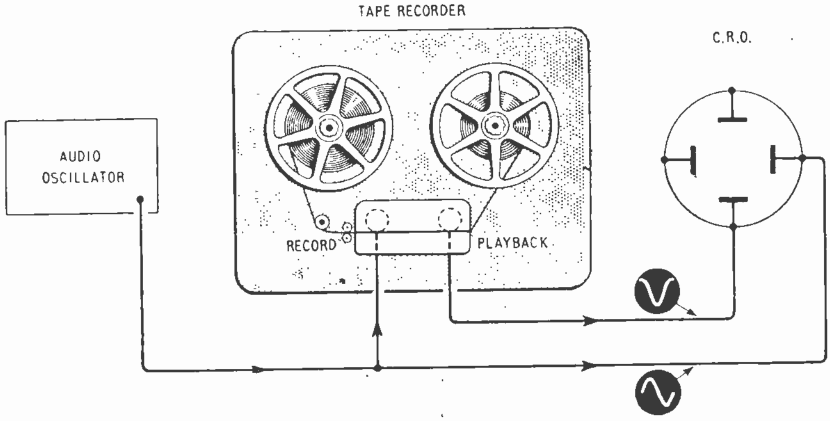


Fig. 1. Set-up for measuring "wow" with a cathode-ray oscilloscope.

[1] See for example Fig 4 of "Cathode Ray," *Wireless World*, Nov. 1955, p. 554.

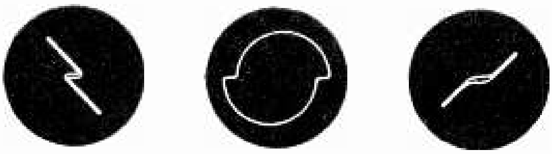


Fig. 3. When using the erase head without bias for recording, the waveform is distorted but still indicates phase.

any faults in the transport mechanism, we carry out the same procedure as before and find that the movement of the pattern is barely discernible. We can now slowly increase the frequency, pausing each time the pattern becomes a circle; we are, in effect, increasing the number of whole cycles between the heads and consequently the sensitivity of the system. If we found that we had a 180° phase swing at a frequency of 750 c/s the "wow" would obviously be 0.25%—at 1500 c/s, 0.125% and so on up the scale. The only limit to the method is the highest frequency which the recorder will accept. The input can always be increased as the response of the playback head and amplifier fall off at the higher frequencies.

The method can still be used, even if, as in the majority of tape recorders available on the home market, the same head is used for recording and playback. With the recorder switched to playback the erase oscillator is switched off and the erase head can be used as a recording head. With a high impedance head, fed via a small capacitor from the erase oscillator anode, the tone can be fed straight across the head; with a low-impedance, transformer-fed head, it is better to disconnect the transformer from the head. The waveform will of course be distorted, Fig. 3, but this is no disadvantage. On the other hand, it will be found that high-frequency attenuation is more severe, due to the relatively large gap of this head, but a sufficiently high frequency can be used to measure "wow" on all but the very highest quality equipments, and as these are usually blessed with at least three heads this limitation does not arise.

There are variations to the method which can be used for checking various "constants" on tape recorders.

1. If the phase shift in the amplifier(s) can be measured the exact distance between the heads can be calculated by using two tones, consecutively, of accurately known frequencies, which give the same phase pattern—preferably a straight line.

2. By choosing a frequency just low enough not to show too much "wow" or "flutter" the speed constancy with variations of mains and of loading (full or empty feed spool) can be checked. An extension of this is to keep a note of a frequency which gives a certain pattern so that the long-term stability of the tape transport mechanism may be checked at any time—this assumes that all phase shifts other than those due to tape speed are kept constant and that the frequency can be reproduced exactly each time.

3. The tape itself can be checked for stretch or shrinkage due to stress, heat, etc. First, record a given tone on the tape, then, after stressing, play it back feeding the audio source at exactly the same frequency to the c.r.t. plates only. The phase will be a matter of luck, but any change in the tape will change the wavelength on it and cause a rotation of the pattern—the rate of rotation being proportional to the amount of stretch, the latter can be deduced.

It must be noted here that these variations are extremely sensitive, not only to the quantities being measured but also to frequency changes of the applied audio source, and only hold good if equipment of the highest accuracy is used. Before you write to your tape or recorder manufacturer make sure that your audio generator is beyond reproach—or do as I do and compare it, during the test, with the standard audio frequencies radiated from Rugby.[2] Almost any R-C oscillator and most good beat-frequency oscillators will maintain their frequency for at least the few minutes required to carry out a test for "wow" or "flutter."

APPENDIX

THE percentage "wow" or "flutter," W can be calculated from the formula:

$$W = \frac{UV \times 100}{FD} \%$$

Where U=phase difference, expressed as a fraction of a cycle, V=tape speed, F=recorded frequency, and D=distance between heads.

If it is decided to work with a phase difference of 180°, as suggested, the formula simplifies to

$$W = \frac{V \times 100}{2FD} \%$$

[2] *Wireless World*, June 1953, p. 267.

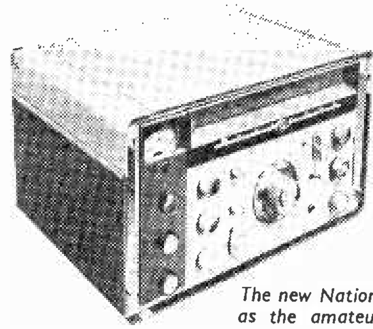
Amateurs' Dream Receiver

WHAT is a dream receiver? If you are a radio amateur the NC300, just introduced by the National Company of America after studying thousands of different suggestions submitted from all over the world, might be the answer.

This set is a 10-valve double superheterodyne with a first i.f. of 2,215 kc/s and a second of 80 kc/s. It covers all the amateur bands from 10 to 160 metres with built-in circuits and the 1¼-, 2- and 6-metre bands with the aid of an external convertor. Separate scales for all bands, including those covered by the convertor, are provided.

Since the set is intended for expert handling, a very full complement of controls is provided; no fewer than 14, to be exact. They include r.f., i.f. and a.f. gain and tone controls; switching for a.m., c.w. and s.s.b., crystal filter and calibrator; bandwidth, band-change and tuning. A three-position i.f. selectivity selector gives the choice of 0.5-kc/s, 3.5-kc/s or 8-kc/s bandwidth, while a special linear detector, in conjunction with very stable oscillators, ensures the best possible conditions for single-sideband reception, which is becoming a widely used system in amateur circles.

The NC300 is 19½in wide, 11¼in high and 15in deep and is finished in two-tone grey enamel. And the price? Well, in the U.S.A. $349.95!



The new National NC300, described as the amateurs' dream receiver.

FEBRUARY MEETINGS

LONDON

8th. I.E.E.—"Pulse techniques with particular reference to line and radio communication" by Dr. E. M. Deloraine at 5.30 at Savoy Place, W.C.2.

8th. British Kinematograph Society. —"Practical acoustics and cinema auditoria" by J. Carson at 7.15 at the Holborn Town Hall, W.C.1.

10th. Junior Institution of Engineers.—"A production control system incorporating an electronic computer" by W. J. Kease at 7.0 at Pepys House, 14, Rochester Row, S.W.1.

14th. I.E.E.—"An on-off servo-mechanism with predicted changeover" by J. F. Coales and A. R. M. Noton at 5.30 at Savoy Place, W.C.2.

15th. British Kinematograph Society. —"Synchronous sound recording using the syncropulse process" by N. Leevers at 7.15 at the Holborn Town Hall, High Holborn, W.C.1.

17th. B.S.R.A.—"Acoustics of small rooms" by J. Moir at 7.15 at the Royal Society of Arts, John Adam Street, W.C.2.

20th. I.E.E. "Ultrasonics in industry" by C. F. Brocklesby (with films and demonstration), at 5.30 at Savoy Place, W.C.2.

21st. Television Society.—"Some problems in a band-sharing colour television system" by A. V. Lord (B.B.C. Research) at 7.0 at the Institute of Education, Malet Street, W.C.1.*

23rd. Physical Society.—"Physiological and psychological effects of noise" by D. E. Broadbent at 5.30 at the National Hospital, Queens Square, W.C.1.

24th. R.S.G.B.—Talks on and demonstrations of u.h.f. operation at 6.30 at the I.E.E., Savoy Place, Victoria Embankment, W.C.2.

28th. Television Society.—"Development of 21-in colour television receiver" by H. A. Fairhurst (Murphy Radio) at 7.0 at the Institute of Education, Malet Street, W.C.1.*

29th. Brit.I.R.E.—"Technique of microwave measurements" discussion opened by E. M. Wareham at 6.30 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

29th. British Kinematograph Society. —"The building of the independent television news service" by P. H. Dorté at 7.15 at the Holborn Town Hall, High Holborn, W.C.1.

BELFAST

14th. I.E.E.—"Tridac: a large analogue computing machine" by Lt. Cdr. F. R. J. Spearman, J. J. Gait, A. V. Hemingway and R. W. Hynes at 6.30 in Lecture Room A, Engineering Department, Queens University.

BIRMINGHAM

27th. I.E.E.—Short papers on "The theory, application and manufacture of transistors" by Dr. A. F. Gibson, S. W. Noble and B. B. Frusztajer at 6.0 at the James Watt Memorial Institute, Great Charles Street.

CHELTENHAM

13th. Society of Instrument Technology.—"Closed-circuit television" by J. E. H. Brace (Marconi's) at 7.30 at the Rotunda.

* Tickets, price 2/6, must be obtained from 164, Shaftesbury Avenue, London, W.C.2.

EDINBURGH

9th. Brit.I.R.E.—Film evening at 7.0 at the Department of Natural Philosophy, University of Edinburgh.

GLASGOW

22nd. Brit.I.R.E.—"Colour television" by B. V. Somes-Charlton at 7.0 at the Institution of Engineers and Shipbuilders, 39, Elmbank Crescent.

HALIFAX

6th. Institution of Production Engineers.—"Computer controlled machine tools" by H. Ogden at 7.15 at the White Swan Hotel.

LIVERPOOL

1st. Brit.I.R.E.—"Development of a design for an angle modulation radio link" by H. C. Spencer at 7.0 at the Chamber of Commerce, 1, Old Hall Street.

LOUGHBOROUGH

7th. I.E.E.—"The generation and synthesis of music by electrical means" by A. Douglas at 6.30 at Loughborough College.

MANCHESTER

2nd. Brit.I.R.E.—"Design of battery-operated frequency-modulation receivers" by R. A. Lampitt at 6.30 at Reynolds Hall, College of Technology, Sackville Street.

8th. Television Society.—Annual general meeting of N.W. Centre at 7.30 at the College of Technology, Sackville Street.

15th. I.E.E.—"Pulse time modulation terminals for music transmission over radio links" by R. F. Rous at 6.45 at the Engineers' Club, Albert Square.

NEWCASTLE-UPON-TYNE

8th. Brit.I.R.E.—Papers read by students at 6.0 at Neville Hall, Westgate Road.

15th. Society of Instrument Technology.—"Ultrasonics" by E. G. Richardson at 7.0 in Stephenson Building, Kings' College.

PORTSMOUTH

1st. B.S.R.A.—"Electronic Music" by R. L. West and J. W. T. Roope at 7.30 in the Lecture Hall, Central Library.

RUGBY

14th. I.E.E.—"The new high-frequency transmitting station at Rugby" by Capt. C. F. Booth and B. N. MacLarty at 6.30 at Rugby Radio Station.

STONE

10th. I.E.E.—"Colour television" by L. C. Jesty at 7.0 at Duncan Hall.

TORQUAY

2nd. B.S.R.A.—"The romantic history of the gramophone" by P. Wilson at 7.45 at Callard's Café.

TREFOREST

22nd. Brit.I.R.E.—"Colour television" by Dr. G. N. Patchett at 6.30 at the Glamorgan Technical College.

WOLVERHAMPTON

8th. Brit.I.R.E.—"The ionophone loudspeaker" by A. E. Falkus at 7.15 at the Wolverhampton and Staffordshire Technical College, Wulfruna Street.

RANDOM RADIATIONS

By "DIALLIST"

V.H.F. Sound Success

THE new v.h.f. stations at Pontop Pike and Wenvoe have made a good start and are enabling not a few people who had almost given up using their wireless sets, except for the news, to enjoy plays, concerts and talks once more. So far, Wenvoe is sending out only the Welsh Home Service with an e.r.p. of but 30 kW. Before long all three programmes will be radiated and the e.r.p. increased to 120 kW. By the end of the year over 80 per cent of our population should be able to receive the f.m. transmissions. I hope that those now afflicted by interference of one kind or another won't be slow to realize the benefits of the new service when it comes their way. It means listening with real pleasure and not with the kind of exasperation that so many have known of late.

Mid-frequencies

Had you noticed, I wonder, how the B.B.C. has allotted the three carrier frequencies to each of its f.m. transmitters? In every case that assigned to the Third Programme is the mean of the other two. Wrotham, for instance, has Light 89.1 Mc/s, Third 91.3 Mc/s, Home 93.5 Mc/s. This was done, presumably, after careful experiments with receiving aerials. Obviously you couldn't (or at any rate wouldn't) put up three arrays for your f.m. reception. By keeping each trio of frequencies as narrow as possible and using the mid-frequency for one transmission they've been at pains to ensure that a single array resonant at the mid-frequency will give satisfactory results on all three channels. The half-wavelengths corresponding to Wrotham's carrier frequencies are 1.68 m, 1.64 m and 1.60 m; so there's less than 4 cm "error" (when you allow for end-effect) when the "Light" is being received and slightly less on the "Home."

F.M. on the TV Aerial?

Will some of those served by horizontally polarized Band I television transmitters be able to use the TV aerial for Band II f.m. reception? If the range is short or moderately so, I rather fancy that a number of them will. My TV station, for example, is Tacolneston, the mean of whose sound and vision frequencies is 55 Mc/s. When the f.m. transmitter gets to work later in the year its mid-frequency will be 91.9 Mc/s. Nothing like an exact multiple, I admit; but I've an idea that the horizontal television aerial should be able to do something about a 120-kW horizontally polarized f.m. transmission at a range of under 30 miles, even if its dimensions are a good bit out. Readers living in the area served by Pontop Pike may have tried the experiment of yoking f.m. receivers to horizontal TV aerials. If any have done so with success, I'd be glad to hear from them and to pass on their reports for the benefit of others. In their case the figures are: mid-frequency sound and vision, 65 Mc/s; mid-frequency f.m., 90.7 Mc/s. And there's one other rather important point: have any of them found any interference from the f.m. transmission with the TV signal?

Clearing the Way

ONE of the most urgent tasks now facing the P.M.G. is the clearing of Band III to make way for the eight television channels which it is supposed to accommodate. It's still cluttered up with other transmissions, for which room will have to be found somewhere else, and channels 8 and 9 appear to be the only ones yet available. One reason why the clearance should be made as quickly as possible is that in general Band III TV stations are turning out to have ranges which, at any rate in some directions, are a good deal longer than was expected. Until we can find out by experiment at what distances stations using the same carrier frequencies and with the same polarization interfere with one another I don't see how a proper channel allocation can be planned.

Eight Channels or Sixteen?

Some may think that there's no need for any particular hurry, since Croydon, Lichfield and Winter Hill are likely to be the only Band III transmitters at work this year. But the I.T.A. must be able to plan ahead. And what about the B.B.C.? The I.T.A. says that it will need the whole of the eight channels to give country-wide coverage; but the B.B.C. seems to think that it should have half of them for its second TV programme. If a horizontal receiving aerial proves on this band to be an adequate excluder of vertically polarized transmissions and t'other way about as well, then the eight channels can be turned into sixteen. But to make sure a series of practical tests will have to be made, for queer things can happen to the polarization of v.h.f. What we mustn't do is to drift into a hand-to-mouth, hope-for-the-best channel allocation on Band III.

Rotatable Aerials

WHEN Croydon is joined by Lichfield and Winter Hill, people living in certain areas may have three television programmes available, one from their B.B.C. station and two others from the I.T.A. When I say that the programmes will be available, I don't mean that everyone in such localities will be able to get them, even if he has a 13-channel receiver and a Band III aerial. What will usually prevent reception of more than one of the two possible I.T.A. programmes is that the aerial won't be pointing in the right direction to bring in the other. In the United States, in places where numerous programmes are on tap, the TV "antenna array"—and some of them are fearsome looking outfits—is rotatable. Some you turn by hand; others are provided with a motor to do the work for you. I'm wondering whether there wouldn't be a market for rotatable aerials in places of the kind I'm talking about.

Simplifying Things

At the moment, if we want to receive B.B.C. and I.T.A. television and f.m. as well, we need three v.h.f. aerials. It would be a whole lot simpler and tidier if some of our clever aerial people could design an array that was really universal. I know that arrays built to cover all the channels of several bands are, in theory at any rate, not very efficient. But they seem to work satisfactorily in the United States and I don't see why they shouldn't be successful here. One of the bugbears of television to-day is that if you move into an area served by a different B.B.C. television station, it's long odds that your existing aerial won't be of any use at your new place. And unless we can develop band-covering arrays, the same sort of thing is bound to happen when all, or most, of channels 6 to 13 are in use.

UNBIASED

By FREE GRID

Ignorance in High Places?

JUDGES of the High Court often appear astonishingly ignorant of the workaday world, as, for instance, when one of them asked whether Mae West was the inventor of the life-saving jacket which bears her name. Such ignorance—or at any rate *apparent* ignorance—is not confined to the judicial bench, as is shown when leading radio men say they don't know the reason why a capacitor was, before the etymological renaissance, called a condenser.

Little did I think that I should find this sort of thing so near home until recently, when I happened to be

When doctors differ

reading a book written by one of the stars of the radio firmament who writes in *Wireless World* under the very apt pseudonym of "Cathode Ray." On page 387 of "Second Thoughts on Radio Theory" there appear these words: "and a thing for capacitance is called—why, heaven knows!—a condenser."

Now, lest I be accused of the old political trick of deliberately seeking to falsify meaning by tearing words out of their context, I ought to explain, for the benefit of those of you who have not yet read the book, that in the passage in question "Cathode Ray" is dealing with learners' difficulties, and it is possible that the ignorance does not exist in the author's mind at all; it may be a sort of "Aunt Sally" put in the reader's thoughts for him to demolish.

Many of his fellow peers of the pen have, however, deliberately stated the name of "condenser" to be absurd because "it condenses nothing." Surely this lamentable statement is the very nadir of ignorance, for it is precisely what it *does* do, and I cannot help feeling that this was realized in 1782 when a Leyden jar was first called a condenser.

To "condense" means, among other things, to "bring together closely" (O.E.D.). This is exactly what is done when a capacitor is shunted across the terminals of a simple electrical pump such as a dry cell. The electrons—or the electrical "fluid" of 1782—are indeed brought together closely on the negative plate. To those who would argue that this is done by withdrawing a corresponding number from the positive plate I would point out that in all forms of compression or condensation the compressed particles are withdrawn from somewhere else as in the case of the air molecules we force into a cycle tyre or the spirals of a spring when we wind up a clock.

"*Rursus Idem Concilium*"

WHEN the Radio Manufacturers' Association was metamorphosed into the Radio Industry Council some years ago, a very good Latin motto, *Radio Maximo Arvo*, was lost to the world. The public relations officer of the R.M.A. at the time when this motto was adopted informed me, over a cup of cocoa, that the official translation of it was "Broadcasting to the Farthest Shore." I pointed out to him that the translation seemed a bit "free" as the literal meaning of the Latin word *radio* is "*I* radiate" or "*I* broadcast." He agreed but told me of the trouble they had had to invent a three-word motto using the initial letters R.M.A.

When the R.I.C. was formed I recollected this and at once wrote to the Editor of *W.W.* suggesting a three-word Latin motto beginning with the new body's initial letters, namely *Rursus Idem Concilium*. Unfortunately, both space and the Editor's temper were short that month and he sternly rejected my suggestion. I still think that there is scope for a three-word R.I.C. motto and I wonder, therefore, whether any of you Latin "scolards" can suggest anything suitable.

My own humble and very hackneyed effort was meant to convey the idea that the new Council would carry on all that was best in the old association, and that, as a guarantee of this, many of those who sat in well-deserved high places in the old body would have similar positions in the new.

The reason for its unsuitability was because of its susceptibility to "free" translation. For instance, one very free, very unkind, very untrue but perfectly sound translation would be "The same old gang again." So, please, use very great care in composing your efforts lest you find yourselves in the dock on a charge of criminal libel and pleading, with a hang-dog look, *hoc egi*, which may be freely translated as "I dunnit."

Plain Vans Wanted

OVER 18 months ago in the issue of June, 1954, "Diallist" complained that television interference, of which he had made an official complaint, disappeared magically when G.P.O. engineers in the familiar green van came to investigate the matter. As the interference re-appeared when the van departed he wondered if the offender had spotted the van.

From recent personal experience I have not the slightest doubt of it, for anything more blatant than the G.P.O. television detector vans would be hard to imagine. When I observed it near my house, and I think everybody in the neighbourhood was aware of it, I hoped that it would trace the offender who ruins the Droitwich transmissions with his obnoxious TV whistle which was in full blast when the van arrived.

I really wondered whether it was one of the G.P.O.'s genuine pirate-detecting vans or merely a dummy designed to scare people into scurrying to the Post Office to buy television licences. To test its abilities I switched on a pre-war unsuppressed electric razor but the van made no move towards my house. I therefore "keyed" the razor, which is of the type fitted with a self-starting commutator motor, and tapped out a rude message in Morse but still no response.

Now if the van were indeed a dummy I don't expect the P.M.G. to admit it, for I daresay the sight of it does make a lot of people scurry to the Post Office, but for genuine detection work surely he should take a leaf out of the book of the late Mr. Drage and use a plain van.

The pack ready to move