Wireless World

ELECTRONICS, RADIO, TELEVISION

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MAY 1956

In This Issue

Editorial Comment 201
World of Wireless 202
Two-Channel Stereophonic Sound Systems *F. H. Brittain and D. M. Leakey* 206
Transistor Digital Computers 210
Letters to the Editor 213
Reproduction from Magnetic Tape Records *M. B. Martin and D. L. A. Smith* 215
Frequency Stabilization of Oscillators .. .. *V. N. Gray* 219
Further Notes on the Simplified Band III Convertor *O. E. Dzierzynski* 221
I.T.A. Midlands Relay 223
Commercial Literature 226
Television Receiver Input Impedance .. .. *J. E. Hopkins* 227
Monitoring Sound Broadcast Programmes .. *T. Somerville* 228
Colour Television in the United States 231
Reliability in Equipment .. .. .. *E. G. Rowe* 232
Short-Wave Conditions 234
Heads, Tails and Noise .. .. .. "*Cathode Ray*" 235
More Lines *Instead of* Colour .. .. .. *D. A. Bell* 239
Manufacturers' Products 241
Television in Germany .. .. *W. Nestel* 242
New Magnetic Materials 247
Random Radiations .. .. "*Diallist*" 248
Unbiased .. .. "*Free Grid*" 250

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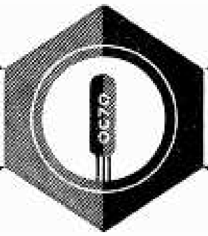
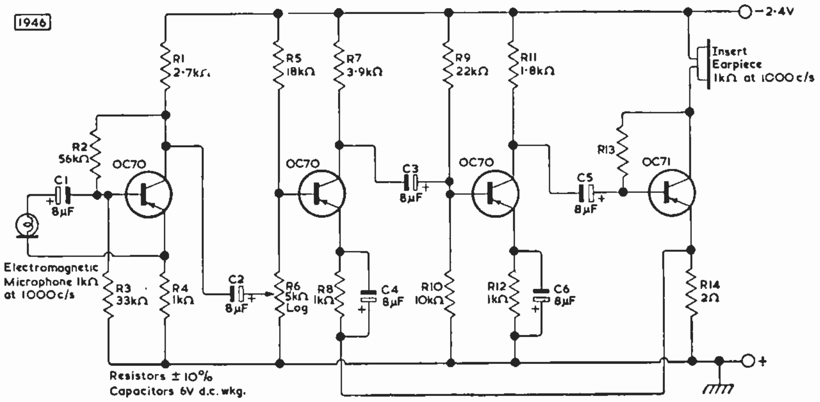
TRANSISTORS IN AUDIO AMPLIFIERS (Part One)



The best known and most practical application of transistors is in low power audio amplifiers. For example, about 90% of the hearing aids made commercially in this country at the present time are transistorised. Although the design of hearing aid circuits is somewhat specialised, the circuit shown here illustrates many of the basic principles of transistor amplifier design.

High gain is obtained by operating the transistors in the grounded emitter connection, that is, with the emitter common to the input and output circuits. The a.c. input is applied between base (b) and emitter (e), and the output current flows between emitter and collector (c). A d.c. base current has to be provided to bias the transistor to the chosen working point. The simplest method is to take the base bias from the h.t. line by a series resistor. If the method is applied to the third OC70 in the circuit, R10 has to be omitted and a new value given to R9. However, some form of d.c. stabilisation is normally included in all audio amplifier stages, since the collector current is dependent on current gain and the very temperature—sensitive collector leakage current $I'_{c(o)}$.

The simplest method of providing some d.c. stabilisation of the working point is shown for the OC71 output stage. The bias resistor R13 is connected to the collector instead of to the h.t. line. When the collector current is higher than its correct value for the d.c. working point, the base current is reduced because of the fall in collector voltage, so that the collector current automatically tends to return to its correct value.



More effective d.c. stabilisation is provided by an emitter resistor and potential divider arrangement such as R9-R10. The current through R9 is greater than that through R10, the difference being the base current which flows from + to − out of the transistor. When the collector current is higher than the required value, the increased voltage drop across the bypassed emitter resistor R12 leaves less voltage available from emitter to base. Hence the base input current is reduced, and the collector current tends to return to its correct value.

The high d.c. stability of the potential divider arrangement is obtained at the expense of slightly higher drain on the battery because of the shunting of R9 + R10. With this arrangement the base current can be reversed into the positive direction, when the corresponding values of collector current are less than $I'_{c(o)}$; if the process is taken far enough, I_c can be made to approach nearly to $I_{c(o)}$. Here $I'_{c(o)}$ is the value of I_c when the base is open circuit ($I_b=0$). It is related to the diode reverse current $I_{c(o)}$ flowing in the grounded base circuit with the emitter open circuit ($I_e=0$) by the current gain of the transistor appropriate to this low level operation.

Other features of the circuit require only brief mention. R8 and R12 are bypassed for d.c. stabilisation, and while R4 is not bypassed, there is no loss of a.c. gain as the input is applied between base and emitter. A value of 8 or 10μF is typical for the coupling capacitors. The first OC70 provides an input impedance of 1kΩ which matches the microphone and is not appreciably shunted by resistors of the values shown for R2 and R3. Negative feedback (12dB) is applied over three stages from R14, and for maximum undistorted output the value of R13 is chosen to match the α' of the OC71 such that $R13 = \alpha' R_L$.

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Sound in Width and Depth

ALTHOUGH the principle of stereophonic sound reproduction has been a subject for discussion among technicians for a lifetime, and has been demonstrated at intervals since the latter half of the last century, it is only recently that it has become a matter of common experience—as a side-show at exhibitions, in the cinema and even as a medium for concert hall performance.

The advent of first-class commercial twin-track records enables those who can afford the necessary equipment to enjoy a new listening experience in the home which goes far beyond the "three-dimensional" diffusion of sound from a single-channel source. The use of paralleled multiple loudspeakers with divergent axes in conjunction with acoustic reflectors and diffusers offers scope for endless experiment and is capable of giving "atmosphere" and many pleasing effects which are absent from a small single-cone loudspeaker in a simple mounting. Elementary movement of the apparent source can be effected by the simple expedient of "pot-panning" in which panoramic movement of the sound is caused by increasing the volume of sound in one loudspeaker at the expense of another through the medium of a potential divider which may be manually or electronically controlled. All such methods may be conveniently classed as "pseudo-stereophony" even though the results in many cases are far from deserving the derogation implied by the term.

We would admit as stereophonic any system which makes an analysis of the sound field at the source into two or more channels and uses the information in these channels to reconstitute those elements in the original sound which are essential to realism. A successful stereophonic system provides more than the obvious effects of movement and life and is characterized by a subtle clarity and definition which is sustained at all volume levels within the capacity of the reproducing equipment.

Many diverse systems have been proposed and are being used for domestic stereophonic reproduction. Some are founded on mathematical reasoning, others on empirical experience, the best on both. None is yet comprehensive (which accounts for the absence of the word "height" from the title of this comment), or foolproof. Occasionally some incongruous, not to say bizarre, effects can be produced, such as fluctuations in the apparent size of instruments according to the register in which they happen to be played. There are also wide divergencies between different systems in their tolerance to movement on the part of the listener. The heaviest responsibility rests with the recording engineer and the studio manager in seeing that the information recorded on the tape tracks is unambiguous and reasonably proof against the sort of maladjustments which may be expected to occur from time to time at the reproducing end.

The creation of an illusion of reality in reproduced sound depends ultimately on the validity of the listener's mental imagery and on his subconscious ability to reconcile what he now hears with his stored experience of original sounds. Since exact reproduction of the original sound field is impossible, the most to be expected of a sound reproducing system is that it shall fire the imagination and not introduce any recognizable incongruity.

By this criterion a single-channel system may prove to be the better for some kinds of sound source; the speaking voice, for example, or a solo instrument such as the guitar recorded without reverberation at the source with the object of reproducing it with only the acoustic environment of the listening room. We have heard examples of this technique, of which C. E. Watts is a recognized exponent, that create a perfect illusion that the performance is in the room. Remarkable results are frequently achieved by the B.B.C. through their single-channel sound broadcasting system in giving an illusion of auditory depth by skilful variation and control of the ratio of direct to reverberant sound at the microphones.

Clearly the choice of method must rest primarily with the material to be reproduced. Stereophonic sound is a powerful new addition to the means available for realistic sound reproduction, but in the foreseeable future it will not automatically displace the single-channel system.

WORLD OF WIRELESS

Organizational, Personal and Industrial Notes and News

London I.T.A. Station

BECAUSE of the Government curb on capital expenditure it is now unlikely that the I.T.A. London station will move from Croydon to Crystal Palace next year as planned. The Authority is, therefore, installing a second transmitter at Croydon.

The original transmitter was a prototype lent by Marconi's to expedite the opening of the service. Whether or not that will be retained in service so that the output of the station can be increased to the planned 120 kW e.r.p. or the new transmitter replace the original, is uncertain. The phasing equipment is certainly being installed in readiness for ultimately operating two transmitters in parallel at Croydon.

Radio "Balance Sheet"

DIRECT exports of British radio and electronic equipment during the first quarter of the year were again a record. As will be seen from the figures extracted from the Government's "Trade and Navigation Accounts" the exports from each section of the industry—with the exception of valves—increased by comparison with the first quarter of last year. The overall increase was 17.5 per cent.

It will also be seen that the imports during the same period increased, although not so steeply.

	Exports (£M)		Imports (£M)	
	1956	1955	1956	1955
Transmitters and navigational aids	3.66	2.92	0.61	0.41
Valves and c.r. tubes	0.71	0.73	0.85	0.73
Receivers	1.05	0.97	1.54	1.29
Sound reproducing gear ...	1.73	1.30		
Components and test gear ...	1.98	1.72		
	9.13	7.64	3.00	2.43

"Stereosonic" Concert

A PUBLIC recital of music from H.M.V. "Stereosonic" tape records given in the Royal Festival Hall on 26th April was well attended and enthusiastically received. The programme included orchestral, operatic, organ, piano, violin and solo vocal items which in tonal quality and "presence" were a very close approximation to the real thing. The illusion was strengthened by clever stage lighting in which the orchestral desks and some solo instruments were pin-pointed in the darkened hall.

Normal "Stereosonic" reproducing equipment was used up to the main amplifiers, the power of which was increased to 120 watts for this occasion. The loudspeakers comprised banks of elliptical moving coils for the bass, ribbon units for the upper middle register and electrostatic units for the extreme top. These were assembled in large baffles, one on each side of the stage with their axes directed to give optimum results in the middle stalls. The effects were fundamentally the same as those to be expected from domestic "Stereosonic" equipment.

Jamming: A Two-edged Weapon

IN a concerted effort to stop the use of jamming, the International Short Wave Club has launched a campaign in which it calls on all short-wave listeners to stop sending reception reports to countries operating these "disturbers of the peace." The countries concerned are listed in the following extract from a Foreign Office letter quoted by the I.S.W.C.: "Stations engaged in the systematic and indiscriminate jamming of foreign broadcasts are situated in the Soviet Union, East Germany, Poland, Czechoslovakia, Hungary, Rumania and Bulgaria. It has been established that over a thousand jamming stations operate from these territories." The I.S.W.C. statement goes on to express the hope that the British jamming of Greek broadcasts will cease.

Wireless World commented editorially on international jamming in March, 1940, shortly after the outbreak of World War II. The views then expressed may be thought to have some relevance even to-day:—

> Why . . . do we not institute a campaign of intensive jamming against all German communications? . . . Great Britain and her ally France, having access to jamming sites throughout the world, are very favourably situated geographically for hampering the enemy's wireless communications.
>
> The answer to this question is not far to seek. In the first place, jamming of non-military communications is a typical example of the kind of international lawlessness we are fighting against, and one can rest assured it would only be resorted to by way of reprisal and in the face of the most severe provocation. Large-scale jamming, it must be remembered, would interfere not only with Germany but also with the rights of neutral nations.

Receiver Sales

DESPITE the increased television coverage in Bands I and III provided during the last few months by both B.B.C. and I.T.A., sales of television receivers in the first quarter of the year were some 18.5% below the figure for the same period last year. It will be seen from the table, issued by the British Radio Equipment Manufacturers' Association, that the percentage decrease in the sales of sound receivers and radiograms was even higher—31.5% and 51% respectively.

The hire purchase or credit sales in March (as a percentage of the total sale) were: sound 31%, radiograms 54% and television 46%. The comparable figures for March, 1955, were 41%, 62% and 59% respectively.

	Sound		Radiograms		Television	
	1956	1955	1956	1955	1956	1955
Jan.	66,000	98,000	18,000	35,000	85,000	103,000
Feb.	66,000	99,000	15,000	33,000	81,000	98,000
Mar.	67,000	95,000	12,000	24,000	67,000	85,000
Totals	199,000	292,000	45,000	92,000	233,000	286,000
	—31.5%		—51%		—18.5%	

PERSONALITIES

Sir Edward Appleton, K.C.B., D.Sc., F.R.S., has accepted an invitation to give this year's Reith lectures on "Science and the Nation" which will be broadcast by the B.B.C. in the autumn. Sir Edward, who is in his early sixties, has been principal and vice-chancellor of the University of Edinburgh since 1949. For the previous ten years he was secretary of the Department of Scientific and Industrial Research. In 1924 he was appointed Wheatstone Professor of Physics at King's College, London, where he remained for twelve years. It was during this period that his researches led to the discovery of what is now known as the Appleton layer.

Sir Ben Lockspeiser, K.C.B., F.R.S., has retired from the post of secretary of the D.S.I.R. on reaching the age of 65. Before his appointment in 1949 he had been chief scientist in the Ministry of Supply for three years. He will be succeeded at D.S.I.R. by **Professor H. W. Melville,** F.R.S., who has been Mason Professor of Chemistry in the University of Birmingham since 1948.

Dr. W. Shockley is to take charge of the Shockley Semiconductor Laboratory set up at Stanford, California, by Beckman Instruments Inc., which he joined a few months ago. Dr. Shockley, "father of the transistor," was for nearly 20 years with Bell Telephone Laboratories where he was latterly director of transistor physics research.

H. Anglès d'Auriac has resigned from the directorship of the Technical Centre of the European Broadcasting Union in Brussels. In 1946 he was seconded from the French broadcasting service to become director of the Technical Centre which was then operated by the International Broadcasting Organization. M. d'Auriac, who is 46, is succeeded as director by **Georges Hansen** who for nine years has been chief engineer and deputy director general of the Belgian broadcasting organization—Institut National Belge de Radiodiffusion. M. Hansen, who from 1940 to 1945 served with the Belgian Forces in this country, is vice-chairman of the C.C.I.R. Study Group XI (Television) which has recently concluded an international survey of colour television.

R. A. Cail has left E.M.I. Engineering Development Ltd., where, since 1953, he had been senior engineer, to become chief engineer of Bonochord Limited who are entering the field of automation. Whilst at E.M.I. he was responsible for the design of the first British numerically controlled production milling machine. Except for his war service at the Royal Aircraft Establishment, Mr. Cail was from 1935 to 1953 with McMichael Radio where, for seven years, he was assistant chief engineer. **Dr. F. Roberts,** M.Sc., who was with the Bendix Aviation Corporation in the United States, has also joined Bonochord as senior development engineer.

J. Thomson, M.A., D.Sc., is the new director of the British Scientific Instrument Research Association in succession to **A. J. Philpot,** C.B.E., M.A., B.Sc., who is retiring after 36 years with the Association. Dr. Thomson, who is 51, joined the Admiralty Signal School, Portsmouth, in 1939 and after spending the war years in research on micro-wave devices and the years immediately after the war in developing tactical radio communication equipment for the Navy, he was appointed professor of physics and electrical engineering at the Royal Naval College, Greenwich. Since 1951 he has been deputy director of physical research at the Admiralty with responsibility for research and development of valves on behalf of the three Services. Dr. Thomson is author of the recently published third volume of "The Services' Textbook of Radio," entitled "Electronics," which covers valves, c.r. tubes and transistors.

A. B. Pippard, M.A., Ph.D., elected a F.R.S. "for his work on the electrical properties of metals at radio-frequencies, and for his studies of the super conducting state," has been lecturer in physics at Cambridge since 1950 but is at present visiting professor at the Institute for Study of Metals, University of Chicago. During the war (1941 to 1945) Dr. Pippard, who is 35, was in the Scientific Civil Service engaged on the design of microwave transmission systems and radar aerials.

R. G. Colby, chief of the radio and television test section of A. C. Cossor Limited, at Highbury, since 1951, has been appointed manager of the company's service department at 51 Calthorpe Street, London, W.C.1. (Tel.: Terminus 0077.) He has been with Cossor since 1937, having previously been on the staff of E.M.I. During the war he was chief inspector at two of the Cossor shadow factories.

W. R. Daniels, who was until recently with the Pye organization where he was working on photo-conduction camera tubes, has joined 20th Century Electronics Limited as production engineer. For some years he worked with Professor Lallemand in Paris and has considerable experience in the photo-electric field particularly in relation to pick-up tubes, multipliers and radiation detection devices.

Sydney H. Brewell, M.B.E., the new chairman of the Radio and Electronic Component Manufacturers' Federation, is chairman and managing director of A. H. Hunt (Capacitors), Ltd. He is also vice-president of Hunt Capacitors (Canada), Ltd., formed two years ago. Before joining Hunts in 1932, Mr. Brewell was for three years with the Gramophone Company.

J. W. Soulsby, the new chairman of the Radio Officers' Union, has been a seagoing radio officer with the Marconi Company since 1918 and a member of the Union's executive committee since 1944. He is 56.

The new vice-chairman of the Radio Officers' Union is **G. W. Cussans,** who started his radio career as an


Sir Edward APPLETON.


R. A. CAIL.


S. H. BREWELL.


W. R. DANIELS.

operator with the Marconi company but subsequently joined what is now B.O.A.C. From 1945 to 1948 he was senior radio instructor at Hythe, Southampton.

C. H. T. Johnson, this year's chairman of the Radio Communication and Electronic Engineering Association, is commercial director of Decca Radar, Limited. He joined the Decca organization in 1946 after war service with the R.A.F. Technical Branch. He was initially concerned with the commercial development of the Decca Navigator System, but since 1950 has been with Decca Radar. He is here shown presenting the R.I.C. technical writing premiums.

OUR AUTHORS

Professor Werner Nestel, chief engineer of Nordwestdeutscher Rundfunk since 1947, describes in this issue the development of television in Germany. Since joining N.W.D.R., the broadcasting organization in what was the British zone of occupation, Dr. Nestel has been largely responsible for the reconstruction of the German broadcasting system, including the introduction of frequency modulation.

M. B. Martin, who, with **D. L. A. Smith,** contributes the article in this issue on reproduction from single-channel and "Stereosonic" tapes, has been deputy section leader of the magnetic recording section of E.M.I. Sales and Service since 1953. He joined the company in 1950 and has been continuously engaged on the design of magnetic recording and reproducing equipment. For two years prior to joining the company he was studying at E.M.I. Institutes. D. L. A. Smith, his co-author, who is project engineer for magnetic recording equipment at E.M.I., was for five years with Addison Electric Company where he was engaged on a.f. development work.

V. N. Gray, author of the article on the frequency stabilization of oscillators, has been with A. H. Hunt (Capacitors), Limited, where he is in charge of the test engineering department, since 1953. His radio career began at Murphy's in 1942. From 1946 to 1948 he was in Royal Signals where he was for most of the time radio instructor in the 1st Training Regiment. He afterwards undertook part-time study and obtained his London (External) B.Sc.

IN BRIEF

At the end of March the total number of **broadcast receiving licences** current in the United Kingdom was 14,261,551, including 5,739,593 for television and 293,459 for car radio. The month's increase in television licences was 90,327.

A Broadsheet is to be issued five times a year by the City and Guilds of London Institute giving information on its activities. In the first issue reference is made to the new four-year course for electrical technicians in which specialization in industrial electronics or electrical power equipment is provided for in the third and fourth years.

B.S.R.A. Show.—As already announced the eighth exhibition organized by the British Sound Recording Association opens at the Waldorf Hotel, Aldwych, London, W.C.2, at 10.0 on Saturday, May 26th. It will remain open until 6.45 and be open again from 10.0 to 6.0 the next day. Admission is by catalogue, price 2s. A list of the thirty-seven exhibitors, twenty-six of whom have booked individual demonstration rooms in the hotel, was given last month.

Television Society Premiums.—Only three of the six premiums normally awarded annually by the Television Society were this year presented at the annual general meeting on May 11th. The Pye premium was given to R. A. Rowden (B.B.C.) for his paper "Television Coverage of Great Britain," the E.M.I. premium to W. S. Percival (E.M.I.) for "Distributed Amplifiers," and the Mullard premium to L. C. Jesty (Marconi) for "Progress in Colour Television." Each premium is valued at £5.

The new president of the **British Wireless Dinner Club** is Vice-Admiral J. P. L. Reid, C.B., C.V.O., and the new vice-president is Air Vice-Marshal E. B. Addison, C.B., C.B.E. Particulars of the club, which was originally formed for past and present members of the radio branches of the three Services but now has a wider membership, are obtainable from Captain F. J. Wylie (director of the Marine Radio Advisory Service, Cory Buildings, 117 Fenchurch Street, London, E.C.3) or L. Hinton (Standard Telephones and Cables), who are joint secretaries.

I.E.E. Radio Section.—The membership of the radio and telecommunication section of the Institution of Electrical Engineers now exceeds 5,000—the largest of the four specialized sections of the Institution. The figure at the end of March was 5,232.

Society of Instrument Technology now has an office at 20 Queen Anne Street, London, W.1 (Tel.: Langham 4251) and Commander A. A. W. Pollard, R.N.(Ret.), has been appointed full-time secretary.

FROM ABROAD

E.B.U.—Changes of personnel and administrative offices are announced by the European Broadcasting Union. H. A. d'Auriac has resigned from the directorship of the Brussels Technical Centre and is succeeded by G. Hansen (see "Personalities"). The chief engineer of the Centre—J. Treeby Dickinson—will also be leaving when his extended term of secondment from the B.B.C. ends this year. The Geneva headquarters of the Union are now at Centre International, Rue de Varembé.

French television on 441-lines has been discontinued as a result of a fire at the Paris transmitter. It was originally planned to scrap the system in 1958 but it is now suggested that the station will not reopen. According to a report in our Paris contemporary, *Television*, owners of 441-line receivers are being given a generous allowance on their old sets when purchasing 819-line receivers.

4,500 kW at 537 Mc/s is the effective radiated power claimed by R.C.A. to have been radiated experimentally by a television station in Lancaster, Pennsylvania. The output of the 100-kW transmitter was fed to an aerial having a gain of nearly 50. The maximum e.r.p. for u.h.f. television stations permitted by the Federal Communications Commission is at present 1,000 kW.

Soviet Receiver Production.—The sixth five-year plan of the U.S.S.R. (1956 to 1960) provides for a 255 per cent increase in the production of sound and television receivers compared with 1955. The output of receivers in 1960 is planned to reach 10.2 millions.

A monument is to be erected in Yugoslavia to mark the centenary in July of the birth of **Nikola Tesla,** whose name will go down to posterity because of his early experiments in the transmission of electrical energy by wireless.

BUSINESS NOTES

Decca Radar announce that in the six years since they entered the marine radar field with their "Woolworth set"—Type 159—their equipment has been ordered for over 5,000 ships of all classes operated by over 1,000 shipowners throughout the world. This figure is stated to be over 30 per cent of the world's radar-equipped vessels. The navies of twenty-seven countries have also fitted Decca radar. Since the smaller version—Type 212—for coasters, etc., was introduced in March last year, over 1,000 have been sold.

The I.T.A.'s second northern television station—on Emley Moor, near Huddersfield—is to be constructed entirely by **Marconi's.** The equipment will be similar to that installed on Winter Hill, Lancs, comprising a 7.5 to 10 kW vision transmitter and 2.5 kW sound transmitter. The aerial, which will be directional, will give a vision e.r.p. of 200 kW.

Sea Wave Communications Limited has been formed with offices and showrooms at 13, South Molton Street, London, W.1, for the manufacture of small transmitters and marine radio-navigational aids. The first two products are a marine portable direction finder and a 25-watt marine radio-telephone. The organization has also been granted the sole distributing rights for the United Kingdom of Hallicrafters communication equipment. The managing director of the company is H. R. Adams (G2NO) who was with the McElroy-Adams Group, until recently Hallicrafters agents in this country. J. G. Maitland-Edwards (G2GS) is also a director.

A division for the design and production of industrial electronic control units has been formed by **Bonochord Limited,** of 48, Welbeck Street, London, W.1. The division will also provide an automation advisory service.

The production of **Belling-Lee** television aerials and accessories has been started in Melbourne by their subsidiary company, Belling & Lee (Australia) Pty., Ltd. Among the members of the firm going to Australia in an advisory capacity is I. A. Davidson, senior research engineer.

The new 5-valve superhet, the Enfo, fitted in the Ford company's Zodiac, Zephyr Six and Consul cars, has been developed and is being manufactured by **E. K. Cole Limited.**

Tape Recorders (Electronics) Limited, makers of the "Editor" and "Playtime" recorders, have moved from Fitzroy Street, London, W.1, to 784-788, High Road, Tottenham, with factories at 14 and 17 Wingate Estate, London, N.17. (Tel.: Tottenham 0811.)

Simon Sound Service have opened a service department, adjoining their main offices, at 46 George Street, Portman Square, London, W 1. The manager is H. Dowsett who has been with the firm nine years.

I.T.U. STAMP.—The work of the International Telecommunication Union is symbolized in this stamp being used by the United Nations postal administration in New York. Across the centre of the design is a morse tape symbolizing telegraphy, the dial in the centre, telephony, and the intersecting circles the radio aspect of the Union's work.

Staar Electronics, Ltd., has been formed by Gas Purification and Chemical Co. Ltd. (of which Grundig and Wolsey Television are subsidiaries) to manufacture and sell in Great Britain and export to the U.S.A. the automatic record-playing equipment developed by Usines Gustave Staar, of Brussels. The managing director of the new company is R. B. Page, who was with Birmingham Sound Reproducers and previously with Plessey. A. E. Johnson, who is an executive of both Grundig and Wolsey, is also a director.

From May 31st, **G.E.C.** broadcast and television receivers will be available from approved radio dealers only.

A serious fire at the Feltham, Middlesex, works of **Valradio Limited** has necessitated the acquisition of new premises. The opportunity has been taken to bring together the departments previously located at Wraysbury, Feltham and Kentish Town, in the new factory and offices at Browells Lane, Feltham, Middlesex. (Tel.: Feltham 4242.)

OVERSEAS TRADE

The list of goods which the **Soviet Union** is desirous of purchasing from the United Kingdom during 1957/60 includes equipment for the manufacture of valves and transistors (75 to 100M roubles), sound and television equipment, measuring and control devices, communication equipment and instruments for the automatic control of technological processes (80 to 100M roubles) and equipment for "manufacturing radio apparatus using printed circuits" (50 to 75M roubles). In a statement from the Board of Trade the first two classes are listed under the heading "Some types are subject to embargo" and the latter class under "Goods about which further information is needed."

The **U.S.S.R.** has ordered two 3-camera television outside broadcast vehicles and ancillary equipment, including centimetric vision and sound links, from Marconi's.

East Germany.—An order for £30,000 worth of television studio equipment for East Germany has been received by Pye Limited as a result of their participation in the Leipzig Fair last February.

Birmingham Sound Reproducers exhibited in the radio and television hall at the German Industries Fair in **Hanover** (April 29th-May 8th).

Iraq's first television station, which was supplied by Pye, started regular broadcasts on May 2nd. The transmitter, which was originally set up at the Baghdad Fair in October, 1954, was subsequently purchased by the Iraq government and has been re-erected on a permanent site.

A radio link providing two reversible television channels between two towns in **Ontario** has been supplied by the G.E.C. The 120-mile link between London and Windsor includes four repeater stations.

Pakistan.—Pye announce the completion of the installation of a radio-telephone service covering the whole length of the gas pipeline between Sui and Karachi, a distance of 350 miles. Eight intermediate relay stations provide a multi-channel radio-telephone and teleprinter service between the two terminals and at five points along the route a mobile radio-telephone service—tied into the main system—is provided for communication with service vehicles, etc. Ericsson Telephones provided the carrier-telephone equipment.

Saudi Arabia.—Dhowaihy and H. Skait, of al-Khobar, have informed the British Embassy at Jedda that they are interested in obtaining United Kingdom agencies for domestic mains receivers, tape recorders and cheap loudspeakers in cabinets. Exporters and manufacturers should write direct to the company and are advised to notify the Commercial Secretariat, British Embassy, Jedda, that they have done so.

Two-Channel Stereophonic Sound Systems

By F. H. BRITTAIN* AND D. M. LEAKEY*, B.Sc.

Basic Requirements for Realistic Sound Location

THE aim of a perfect stereophonic sound-reproducing system is to create for the listeners a similar sound picture in correct aural perspective to that which they would have if transported to an ideal position from which to hear the original sounds. Although this might be possible using a multi-channel system, two channels can, at the best, only recreate the original sounds in correct aural perspective over a limited distance bounded by the two loudspeakers. This is, however, a big improvement over the reproduction available from a single channel system and results in a considerable increase in realism and clarity of the reproduction sound.

The article considers first the particular information used by the brain for the location of sounds, and from a study of this information a two-channel system is devised. In particular a simple method is given for correcting for various listening positions, and it is also shown that the reproduced sound image is more accurately positioned if arrival time differences are overruled and the sound is positioned by intensity differences only.

Information Available for Sound Location.—This subject is dealt with fully in the literature (see, for example, refs. 1, 2, 3). Summarizing the findings of the numerous measurements made it can be said that the brain appears to make use of the following factors:—

(i) Relative loudness of the sound at the two ears.
(ii) Differences in the sound spectrum in the two ears.
(iii) Relative time of arrival and relative phase of sound at the two ears.
(iv) The "quality" of the source as compared with previous knowledge of the quality of a similar source.
(v) The differences both in quality and time of arrival of the direct sound with any reflected sound.

For left-right perception factors (i), (ii), and (iii) appear to be the most important whilst front-back perception and distance perception rely mainly on factors (iv) and (v).

The brain can make use of all the information supplied to it by the ears and the best sound location occurs when all the information is in the same sense. As an example of information in a contradictory sense, in a very live room the reverberation may be louder than the direct sound and arrive from a different position, but by taking into account the late time of arrival of the reverberation the brain is able to ignore the reverberation and to ascertain the true position of the source of sound. This position will not be quite as well defined as it would have been with no reverberation, but it will still be fairly accurate.

Before describing any stereophonic systems, one point of possible confusion should be settled. Throughout these descriptions the term "time difference" between two sounds will be used, and no use of the term "phase difference" will be made. This is because the first is meaningful to random and transient sounds and ambiguous for repetitive waves, whilst the second is relatively meaningless for random and transient sounds but applicable to repetitive waves. Since directional location and stereophonic effects are very much better for random and transient sounds the time difference concept will be used.

Experimental Two-channel system.—Fig. (1) shows the layout of an experimental two-channel system set-up to investigate various effects. It is necessary to give the system an exact size because whilst intensity differences are relative, time delay is a scalar magnitude and will not alter in the same way as intensity differences if the experimental system is made larger or smaller. It was decided at the outset that an attempt would be made to obtain stereophonic reproduction over a front of ten feet and that the listener should be situated somewhere on a line ten feet long and eight feet or more away from the base line of the two loudspeakers.

The first experiment was to ascertain the extent to which two loudspeakers, placed ten feet apart, could simulate a single source of sound when heard by a listener in position L3, that is, equidistant from both loudspeakers and facing the centre of the loudspeaker base line. It was found that with the sound levels from the two loudspeakers equal the listener perceived an apparent single sound source straight in front of him. Extreme movement of the head by the listener tended to produce a splitting of the sound image into two separate sources, but fortunately this effect is not serious unless the listener is consciously trying to listen to each of the loudspeakers independently.

Now if the observer moves from listening position L3 to position L2, then the virtual sound image moves towards one side, in this case towards LSA. This is as would be expected since LSA is now nearer the listener than LSB, and hence the intensity of the sound from LSA is greater and has an arrival time in advance of that from LSB. This is the most serious and the most often encountered fault in two-channel stereophonic systems. It means that the system works correctly only for listening positions on the centre line between the two loudspeakers. However, within limits this fault can be compensated for by the use of directional loudspeakers.

Considering listening position L1 with both loud-

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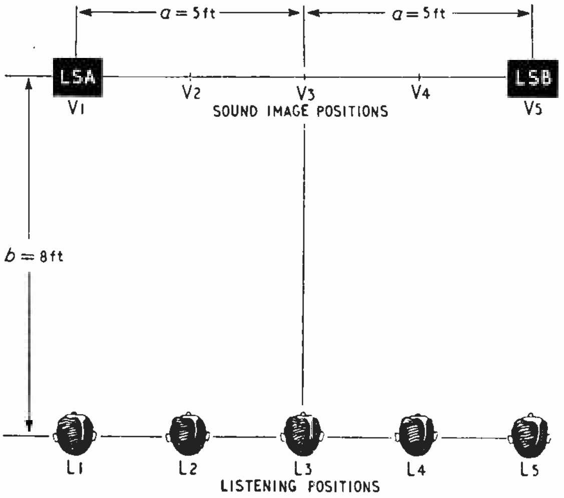


Fig. 1. Layout of experimental stereophonic system in an echo-free room. In this test the loudspeakers LSA and LSB are non-directional in the horizontal plane.

speakers radiating the same random sound at the same level then

Distance LSA to L1 = b

Distance LSB to L1 = $\sqrt{b^2 + 4a^2}$

$\therefore$ At listening position L1 the sound intensity due to LSA will be greater than that due to LSB by the ratio

$$20 \log_{10}\sqrt{\frac{b^2 + 4a^2}{b}}\ \text{dB}$$

$$= 10 \log_{10}\left(1 + \frac{4a^2}{b^2}\right)\ \text{dB}$$

Also the sound from LSA will be in time advance compared with the sound from LSB by an amount proportional to $\sqrt{b^2 + 4a^2} - b$

If the distances are measured in feet, the numerical value gives the approximate time advance in milliseconds.

Correction for Position of Observer.—It has been found that it is possible to correct for both these time and intensity differences and to restore the virtual sound image to the mid position by increasing the sound from LSB and decreasing it from LSA. This implies that time of arrival differences can be compensated by sound intensity differences. Such correction has been found possible for time differences up to a maximum of about five milliseconds, after which the position of the virtual sound image becomes less well defined and compensation for time differences greater than ten milliseconds becomes impossible since the sound then splits up into two distinct sources.

By the above method it is therefore possible to obtain good stereophonic reproduction for a line parallel to the speaker base line as well as for the central listening positions. However, using this method of compensation it is found that the stereophonic reproduction is also greatly improved for the area behind the corrected line and hence it is possible to cover an area with satisfactory stereophonic sound.

Experimental Results.—The test procedure was as follows: the listener was first seated in position L3 and asked to name the position from which the sound appeared to come for different relative sound levels from the two loudspeakers. The sound consisted of a short portion of speech of a few seconds duration only. Fig. 2(a) shows the results of these experiments, each point being the average for a number of listeners, each listener making several determinations for a variety of conditions of differences between the loudspeaker sound levels.

The test was then repeated with the listeners in turn in position L1, the results being shown in Fig. 2(b). Note that in this case of "offset" listening the sound intensity at loudspeaker LSB was always greater than that at LSA but that the overall shape of the curve is the same as that for the central listening position but displaced. As a result of these and other tests for the other listening positions it

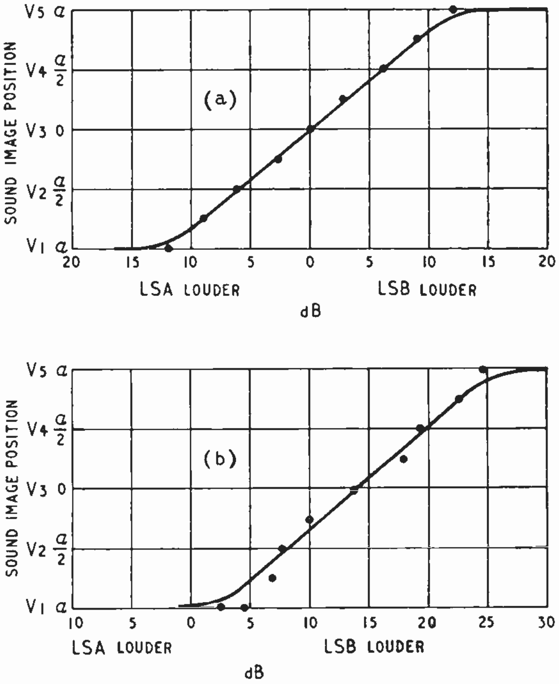


Fig. 2. Movement of sound image by volume difference in the two loudspeakers, (a) for central listening position L3 and (b) for position L1.

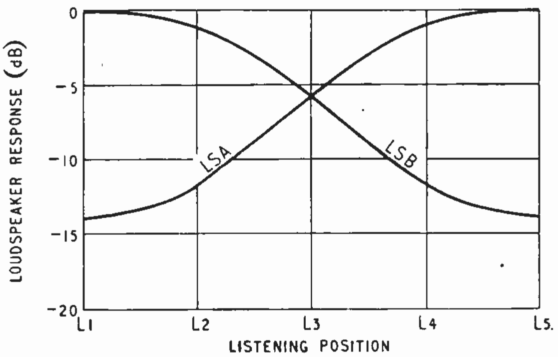


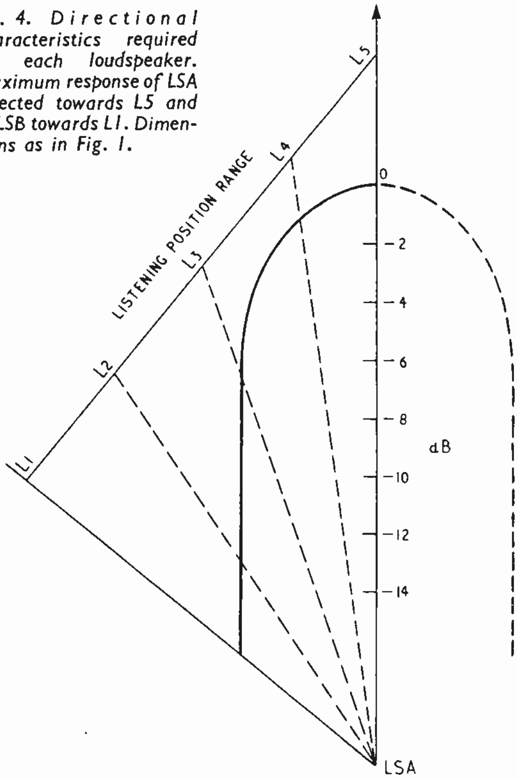
Fig. 3. Loudspeaker responses necessary to correct for off-centre listening positions (Listening line 8ft distant from loudspeakers spaced 10ft apart, as in Fig. 1).

was shown that good definition was possible along the complete listening line.

Directional Loudspeakers.—The above experimental results enable the required ratio of the sound intensities from the loudspeakers towards each listening position to be determined, so as to correct for off-centre listening. As has been indicated, this changing ratio as the listener moves from L1 to L5 can be produced by the use of directional loudspeakers. Considering only the central position for the virtual sound image, which is justified since the sound image position intensity ratio curves were all similar in shape, the requirements to be met can be summarized as:—

(1) The sound image must remain at V3 for listening positions L1 to L5.

Fig. 4. Directional characteristics required for each loudspeaker. Maximum response of LSA directed towards L5 and of LSB towards L1. Dimensions as in Fig. 1.



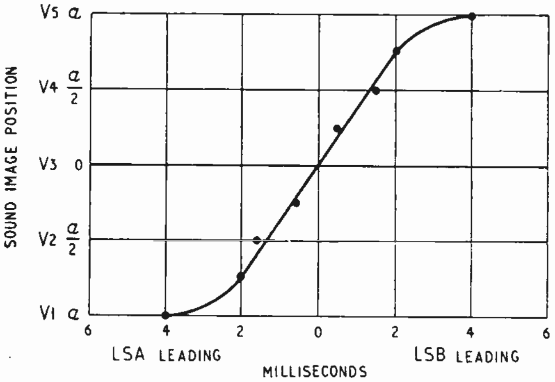


Fig. 5. Movement of the sound image at the central listening position L3 by the introduction of a time difference between the outputs from the two loudspeakers.

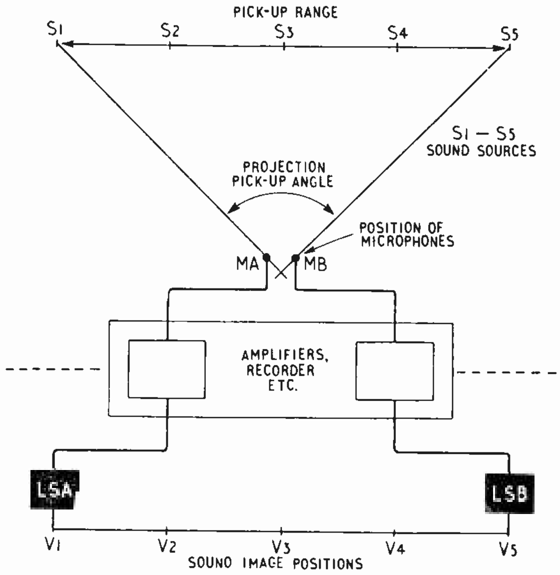
(2) The loudness of the virtual sound image must vary as the observer moves, just as if there was an actual source of sound at V3.

(3) The loudspeaker radiation outside the range directed towards the audience must be reduced as much as possible to prevent undesirable reflections. Reflections are undesirable, since with two loudspeakers the reflections are very liable to be completely different from those which would arise from a single source. This could provide the brain with sufficient information to suggest a splitting of the sound image.

Fig. 3 shows the variation in the sound intensity required from each of the two loudspeakers in the directions of the listening positions to satisfy the above requirements. Fig. 4 shows the same thing plotted as a polar response for one loudspeaker only. This polar response should be independent of frequency; a directional loudspeaker operating at very low frequencies is, however, excessively large, and some compromise must be made. It has been found that for off-centre listening the stereophonic effect does not deteriorate badly if the directionality of the loudspeakers ceases below about 300 c/s and a lower limit of even 1 kc/s provides very acceptable results.

Movement of the Virtual Sound Image.—If the sound is of the character of random noise the virtual sound image can be moved about by two methods. First, as already shown in Fig. 2(a) for an observer at the listening position L3, if the sound intensity levels of the two loudspeakers are different, then the sound image moves towards the louder source. Secondly, if the signal is retarded in time to one loudspeaker, the sound image moves towards the other loudspeaker as illustrated in Fig. 5. In addition a method employing a combination of intensity and time difference could be used and is in fact frequently encountered. It has been found, however, that a sound image moved by an intensity difference between the sound outputs from the loudspeakers remains far sharper and better defined than one where time delay is employed. From Fig. 5 it will

Fig. 6. Complete two-channel stereophonic system.



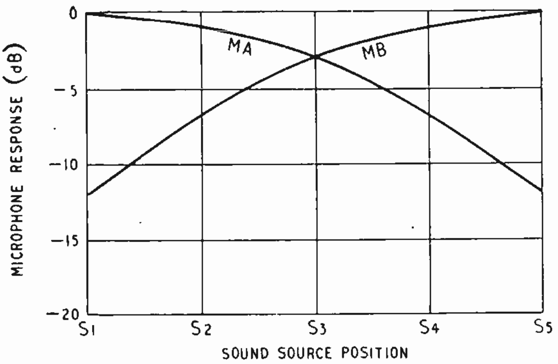


Fig. 7. Microphone responses in direction of indicated sound source for correct positioning of sound images.

be seen that for the experimental system a time delay of about four milliseconds was necessary to move the sound image over to one loudspeaker. Now consider the case if the sound had been repetitive, say with a frequency of 500 c/s. With the loudspeakers radiating the same signal both in intensity and time, the virtual sound image would have been half-way between the loudspeakers. On applying a time delay to one loudspeaker the image would have moved towards the other loudspeaker; however, had the delay been increased to two milliseconds (i.e., one period of the waveform) conditions would have returned to the state of no delay and the sound image would have returned to the central position. Now if the sound had been random or transient in nature it would have remained displaced. Hence for a sound like a piano note which has both a transient part and a fairly steady repetitive component considerable ambiguity would exist as to the exact location of the sound. In practice this effect manifests itself as an apparent widening of the sound image and also as an apparent movement of musical instruments as different notes are played. Hence moving the position of the virtual sound image by varying the intensity levels of the sounds from the loudspeakers is to be preferred.

Sound Pick-up—Microphone Polar Response.—Since it has been shown that the inputs to the two loudspeakers should have a difference of level only and not of arrival time, it follows that the two pick-up microphones should be placed close together to avoid time differences. This in turn calls for some form of directional characteristic or "shadowing" in order that the microphones may differentiate between sound arriving from the left or the right. Before investigating the methods by which these directional characteristics can be produced, it is necessary to ascertain the exact directional characteristics required. Referring to Fig. 6, it is necessary to line up the virtual sound images positions V1 to V5 at the listening end with the actual sound source positions S1 to S5 at the pick-up end of the system. The ratio between the sound intensities from the loudspeakers to position correctly the virtual sound images can be found from Fig. 2(a) and hence the necessary ratio of the responses of the microphones towards each actual sound source can be calculated. At the same time the total output from the loudspeakers must be such that as the virtual sound image is moved from V1 to V5 the loudness changes as if an actual source was moved.

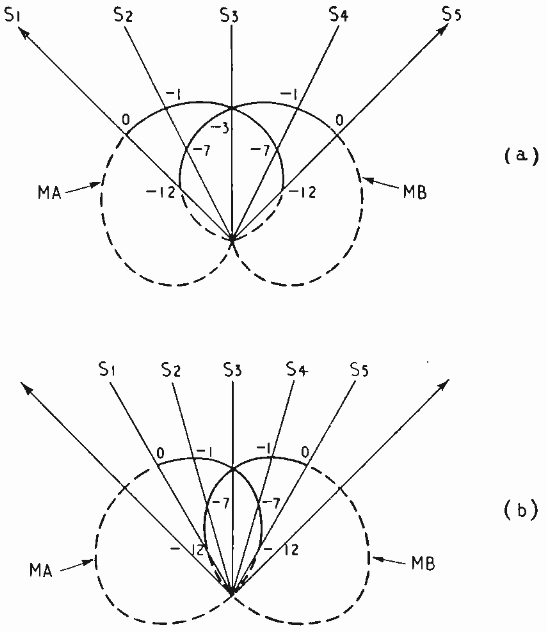


Fig. 8. Polar response curves for microphones for projected pick-up angle (a) of 90° and (b) of 60°.

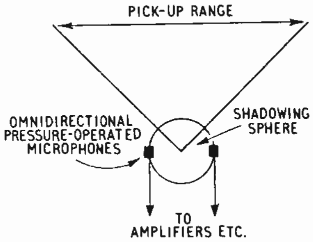


Fig. 9. Stereophonic sound pick-up using artificial head.

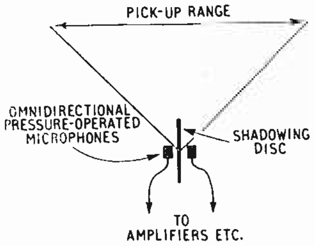


Fig. 10. Stereophonic sound pick-up using shadowing disc.

Fig. 7 shows the necessary microphone responses which satisfy these requirements. Working from Fig. 7 the necessary polar response diagrams can be drawn. Two particular examples are shown in Fig. 8, the first being for a pickup angle of 90° and the second for a pickup angle of 60°.

One of the methods of obtaining the necessary response[4, 5] is to mount two omni-directional microphones in place of the ears in an artificial head as shown in Fig. 9. Such a system depends mainly on intensity difference operated at high frequencies only. Time differences play little part since the maximum time difference which can be obtained from a head of average size is only about 0.6 milliseconds and, as can be seen from Fig. 5, this amount produces little movement.

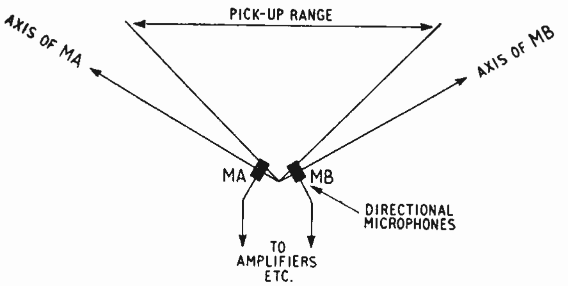


Fig. 11. Stereophonic sound pick-up using directional microphones.

A somewhat similar method shown in Fig. 10 has been developed using a flat "shadow disc" between pressure operated microphones which are otherwise close together. The effect of the "shadow" of the disc is again largely influenced by frequency. The system tends to produce excessive differences at high frequencies and inadequate differences at low frequencies.

Directional microphones placed close together as shown in Fig. 11 give the most satisfactory pick-up from the stereophonic point of view.* Unfortunately it is difficult to make a satisfactory microphone with a polar response independent of frequency. Ribbon microphones can be employed, but if these are used with their axes set at 90° the angle of pick-up is limited to about 60° for correct positioning of the sound images. A great advantage obtained by the use of directional microphones over the artificial head and the "shadow board" is their ability to separate the positions of those low frequency sounds that are important in the reproduction of reverberation. This is still valid even if the directional sound pattern of the loudspeakers is not well maintained at the low-frequency end of the sound spectrum.

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* G.E.C. system and E.M.I. "Stereosonic" System.

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Transistor Digital Computers

NEW BINARY CIRCUIT TECHNIQUES DESCRIBED AT I.E.E. CONVENTION

WHEN the thermionic valve was introduced into digital computing it made possible machines of remarkable versatility and tremendous speed of operation but also brought with it a number of disadvantages. These were perhaps not obvious in the early days, but now, with hundreds of digital computers being sold as commercial products, they are beginning to make themselves felt a little more.

To begin with, the valve has a certain rate of failure and limitation of life. This may not be very important in a domestic broadcast receiver, but in a digital computer, containing anything between 300 and 3,000 valves, it becomes of considerable nuisance value (a graph in another article in this issue (page 232) gives some idea of how reliability of equipment decreases with number of components). Secondly, when several hundred (or thousand) valves are massed together in a single equipment they generate a great deal of heat, and so threaten the reliability of other components—not to mention the kilowatts of electric power consumed in the process. Thirdly, there is the uneconomical size of valves for digital computing operations; considering that most of them do little more than act as simple two-state elements they take up an unnecessary amount of space.

It is only to be expected, therefore, that alternative devices are being sought that will overcome these particular disadvantages. At the moment there are two principal ones—the transistor and the two-state magnetic core. Both are small and robust, produce very little heat, are efficient in operation and appear to have a long expectation of life (so far as we can tell at present). In addition they will both operate from a single source of power of only a few volts.

The possibilities of these devices, and methods of using them in digital computers, were recently discussed at a highly successful convention on digital computer techniques held by the I.E.E. in London. A whole session, in fact, was given over to "The Transistor." This included papers on two complete transistor digital computers, one built at Manchester University and the other at the Atomic Energy Research Establishment, Harwell, while later on there were papers on special computing circuits using combinations of transistors and magnetic cores.

It was interesting to note that both of the complete machines relied principally on point-contact transistors for the computing circuits, and it seems that these devices are still regarded very highly by the computer people, even though everybody else has virtually dismissed them as obsolete. The properties of the point transistor were, of course, recognized very early on as being suitable for pulse and switching circuits. In the first place there was a good frequency response, and secondly, unlike the junction transistor, a negative resistance characteristic that could be used to give a regenerative change-over action in a two-state circuit (equivalent to the Eccles-Jordan valve trigger commonly used in binary computing).*

Unfortunately the point-contact transistor proved

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* See "Transistors—Applications in Trigger Circuits," by Thomas Roddam, *Wireless World,* June, 1953.

to be somewhat unreliable. Apart from its temperature sensitivity, high noise value, general fragility and liability to burn out, it had characteristics which varied widely from unit to unit and this made it difficult to design two-state circuits with consistent "on" and "off" conditions. However, a technique was developed, notably by F. C. Williams, G. B. B. Chaplin and E. H. Cooke-Yarborough, whereby circuits could be designed which were sensibly independent of the individual transistor characteristics. It was not necessary to select the transistors specially nor to adjust the other components according to the different characteristics. This technique consisted of feeding defined currents to the electrodes and involved the use of "catching" diodes and bias supplies to determine the various limiting conditions.

Two-State Pulse Amplifier

Similar methods are, in fact, used in the two complete computers described at the I.E.E. convention. In the Manchester machine the point-contact transistors function principally as pulse amplifiers, while the logical gating operations are done by germanium diodes. The pulse amplifier here is in reality a two-state device with a regenerative switch-over action. It is "set" into the "on" or conducting condition by the incoming digit pulse and "unset" or turned off at the end of each digit period by a regular clock-pulse of 125-kc/s repetition frequency. The output is taken from the collector of the transitor, and has a voltage swing between the defined limits of the "bottomed" condition and a potential at which it is "caught" by a diode. Such two-state circuits are also used in the machine as temporary stores (each circuit storing one digit of a number).

Fig. 1 shows the kind of bi-stable trigger circuit used in the Harwell machine. It is "set" into the conducting condition by discharging rapidly into the emitter a capacitor which forms part of a triggering gate circuit. The triggering pulse causes enough base current to flow to cut off the base-potential "catching" diode momentarily and so raise the base-circuit impedance to a value which produces the desired positive feedback. The regenerative action then takes place and switches the transistor rapidly into the "on" condition. To "unset" the circuit back into the "off" condition a positive pulse is applied to the base of the transistor through the diode shown. The pulse comes from an auxiliary transistor circuit, a mono-stable type, which is actuated by the triggering gate circuit.

The main store of both the computers consists of a magnetic drum. This is basically a slow-access device, but an interesting feature of both machines is that one track of the drum, with its "write" and "read" heads, is used as a quick-access store working on the regenerative delay-line principle.

Another feature of the Harwell computer is a system of interleaving different numbers on the magnetic drum. The arrangement adopted here permits the "reading" of the operands from the drum, the performance of the computing operation and the "writing" of the result back on to the drum all to proceed concurrently. As a result the computing speed of the machine is faster than would normally be possible and this helps to compensate for the slowness of action made necessary by the use of transistors rather than valves.

This slowness of response is, in fact, the main drawback to the use of transistors in digital computers. Whereas in thermionic-valve computers digit-pulse frequencies of 1 or 2 Mc/s are quite normal, with transistors it is difficult to obtain p.r.fs of much above 100 kc/s. A particular problem here is the hole-storage effect caused by the emitter injecting excess holes into the transistor when the collector is in the "bottomed" state (passing no further current). These excess holes cause trouble when an incoming pulse tries to trigger the two-state transistor circuit into the "unset" or non-conducting state, for they produce a continuing current in the collector and as a result the back edge of the output pulse is sloping instead of almost vertical. This, of course, limits the operating p.r.f. of the circuit.

Junction transistors are even less favourable than point transistors in frequency response and consequently have not been used very much in computing circuits. However, the Harwell machine uses some 50 of them in parts of the circuit where the advantages of this kind of device (e.g. low noise) outweigh the poorer frequency response. In the future, of course, when high-frequency junction transistors such as the surface-barrier type become generally available, and the cut-off frequencies are increased to several megacycles, the main limitation of the device in computing circuits will be removed.

One computing application in which the junction transistor is likely to become quite important is the driving of two-state magnetic cores. These cores, which are usually made of ferrite material, are basically storage elements and have hitherto been used for this purpose in storage systems of the matrix type. It now appears that they can also be used as two-state trigger circuits if there is some kind of amplifying device to drive them from one state to the other, and the transistor is the obvious choice for the job. The two states in question are actually conditions of high remanent flux density (almost at saturation point) in the core, and these, and the rapid switch-over from one state to the other, are obtained by virtue of the fact that the core material has an almost rectangular hysteresis loop.

Fig. 2 shows the general principle. Suppose the core is magnetized to saturation in one direction, say to the "1" state, by passing a pulse of current through a winding. At the end of the current pulse the magnetizing field will still be very high—at least 90% of the maximum flux density—thereby retaining the information that the core has been switched into the "1" state. If now another current pulse is passed through another winding so as to apply a magnetizing field in the opposite direction, the

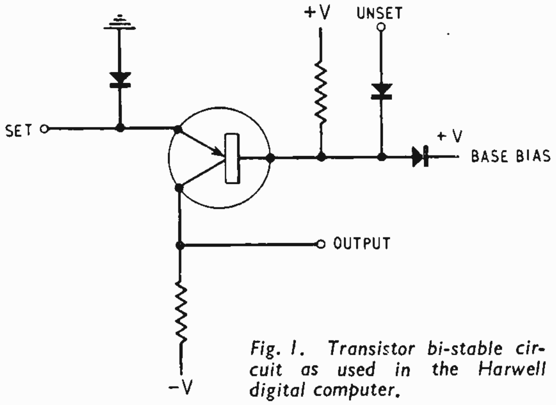


Fig. 1. Transistor bi-stable circuit as used in the Harwell digital computer.

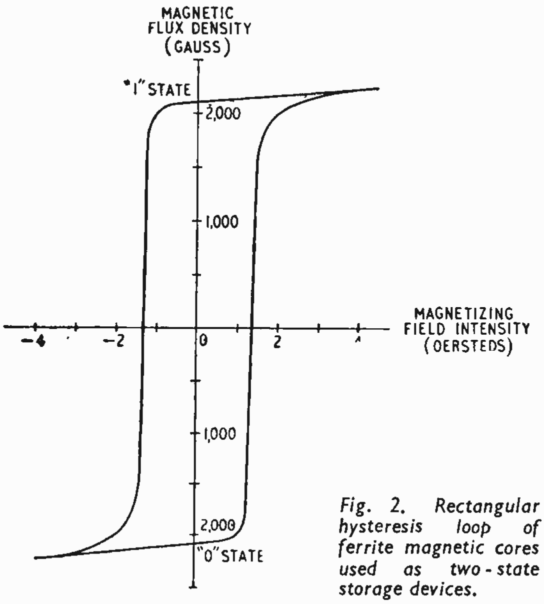


Fig. 2. Rectangular hysteresis loop of ferrite magnetic cores used as two-state storage devices.

magnetic flux will at first decrease slowly then upon reaching the top-left "knee" will suddenly drop to zero and shoot straight up to the opposite saturation point or "0" state. Thus a fairly small increase of magnetizing current will switch the core rapidly from one state to the other, and once the core is in that state it is not critically dependent on the current, which can be reduced to zero without affecting the stored information.

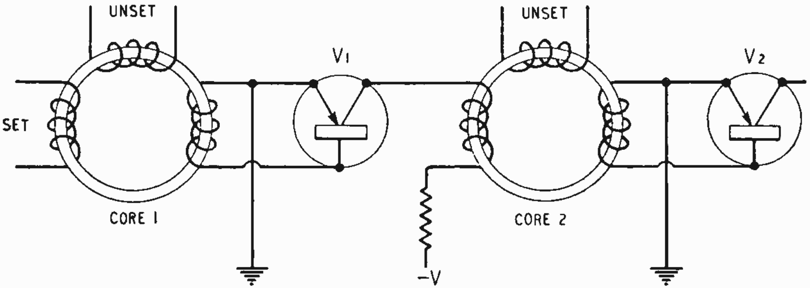
One of the transistor circuits described at the I.E.E. convention in which this type of storage is used is shown in Fig. 3. The basic element consists of one core and one junction transistor, and the core is coupled to the transistor by a winding between base and emitter. Assuming that Core 1 is in the "1" condition and Core 2 is in the "0" condition, a pulse applied to the "unset" winding of Core 1 will change its state and in so doing produce a rapid change of flux which will generate a voltage across the base-emitter winding. This voltage is arranged to drive the base of V_1 negative with respect to the emitter and as a result a considerable current flows in the collector circuit. The collector actually "bottoms" to within a fraction of a volt of the emitter potential, and its current is determined by the resistor and the negative supply. As can be seen, this collector current passes through a winding on Core 2, and the winding is arranged so that it changes the core from the "0" state to the "1" state. Again the transition produces a voltage across the base and emitter of the following transistor (V_2), and this time the base is driven positive and the collector current is switched to almost zero.

In some equipments this simple type of circuit has been used with the addition of positive feedback or regeneration. As shown in Fig. 4, the output current from the transistor is passed back through an additional winding on its own core before going on to the next core. This additional winding is arranged so that the magnetic field generated is in the right direction to assist the transition from one state to the other which has already started in the core. As a result, once the core is triggered it will change its state, using the current of the associated transistor, even though the triggering pulse of current has ended.

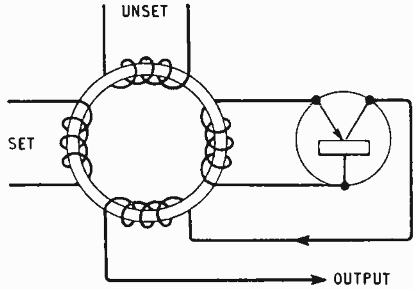
Combined circuits of this kind will work normally at repetition frequencies up to 50 kc/s and, with modifications, up to several hundred kilocycles. The limitation of speed is certainly a drawback but there are a great many attractive features, especially in the regenerative circuit, to compensate for it. In the first place, since the transistor is always cut off except when shifting the core operating point, and since the state of the circuit is maintained purely by the remanent flux, the "standby" power consumption is negligible. Moreover, the input triggering current needed is quite small since it only has to produce a very small change of flux. The circuit permits wide tolerances in component values and transistor characteristics and is consequently very reliable. Finally, the apparatus is extremely small: in one type of computing equipment in which it was used instead of thermionic-valve circuits the overall reduction in size amounted to 100:1—with, incidentally, a 3000:1 reduction in power consumption.

One should not assume from all this, of course, that the thermionic valve is likely to disappear quite soon from digital computers. There are a great many difficulties to be overcome in transistor circuits before this happens. Not only are the transistors too slow, but they have not yet reached the stage of offering a definite commercial advantage over valves in computing equipment. However, the developments which are bound to come in the next year or so—improved power ratings, higher operating frequencies and perhaps reduction in price—are likely to make a big difference to this situation.

Right: Fig. 3. Circuit containing two transistor-core elements, the output of one triggering the other.



Below: Fig. 4. Transistor-core circuit with positive feedback arrangement to give regenerative action.



LETTERS TO THE EDITOR

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

F.M. Discriminators

M. G. SCROGGIE'S article in the April issue points out the advantages of the pulse-counting discriminator, but does not in our opinion give sufficient weight to the difficulties of incorporating it in a practical receiver.* To provide adequate selectivity a rather complicated double superhet circuit is necessary. The alternative—direct conversion to the low intermediate frequency (say, 200 kc/s) required by the characteristics of the discriminator—leaves the circuit open to second-channel interference.

Suppose the signal to be received is at a frequency of 92 Mc/s. If the oscillator is set to 92.2 Mc/s, a signal at 92.4 Mc/s will be received almost equally well, since the r.f. circuits would not provide any substantial attenuation; in fact, signals anywhere in the range about 92 Mc/s might "capture" the receiver. For example, a signal at 91.8 Mc/s or at 92.6 Mc/s would produce an input to the detector at 400 kc/s which would probably lie within the passband. We received a report of a receiver of this type in which interference occurred on the Wrotham Home Service from the Third Programme separated by a frequency difference of 2.2 Mc/s! Ideally, of course, the passband should be just sufficient to accommodate the signal, e.g., 100-300 kc/s. However, the attainment of substantially uniform gain/frequency and linear phase shift/frequency characteristic in this band, with adequate rejection at frequencies adjacent, is likely to be difficult. Even if this were done, there would still be no second-channel protection, and each signal would be received at two settings of the receiver tuning control.

The distortion figures quoted indicated that something less than 1 per cent might be expected. We feel that it should be pointed out that similarly low figures can be obtained consistently with a Foster-Seeley type of discriminator (see, for example, J. G. Spencer; *Wireless World*, December, 1952). The figure quoted by ourselves in the April, 1955, issue for a ratio detector, 3 per cent maximum, is typical for this form of detector. It must be emphasized that the distortion figures quoted are in all cases at maximum output only. By accepting a reduced efficiency, it is possible to reduce the distortion associated with a ratio detector to a very low level.

S. W. AMOS, G. G. JOHNSTONE.

London, W.9.

* No doubt the author will remedy this deficiency when fulfilling his promise to describe a practical receiver in a forthcoming issue.—ED.

B.B.C. Publicity Wanted

MAY I use your columns to reinforce a personal plea put forward by me at a recent meeting of the Radio Industries Club?

In spite of the excellent relations existing between the industry and the B.B.C., radio and radio-like products do not enjoy the amount of broadcast publicity that is regularly accorded, for example, to motor cars, household appliances and books. Surely it is not too much to ask for that the preview of the National Radio Exhibition should be given at least as much programme time on television as, say, the Ideal Home Exhibition.

As things are, little is done by the B.B.C. to inculcate in the public an intelligent interest in sound and television receivers, to say nothing of such domestic sound reproducing equipment as tape recorders and record players.

I suggest that series of programmes on both sound and television should be given in which, for example, the advantages of different types of television receivers could be discussed. The pros and cons of 14-in, 17-in and 21-in screens; the advantages and disadvantages of console and table models; the advisability or not of incorporating a v.h.f. receiver in a television cabinet, are all points which could receive attention.

Possibly a series of programmes devoted to the products of the radio industry could be given, somewhat on the same lines of those which were transmitted recently in regard to the automobile industry.

The advantages of v.h.f. broadcasting might also be hammered home more fully. It seems clear that the majority of the non-technical general public do not really know that it exists. The fact that the areas in which v.h.f. broadcasts can be received coincide with some of the areas served by the television transmitters would presumably make it comparatively easy for a series of television programmes on v.h.f. broadcasting to be transmitted in those areas where the v.h.f. service is already in operation.

Car radio, too, could be encouraged; that, incidentally, would bring extra revenue to the B.B.C., and ultimately, there might be special programmes for car radio users.

Hemel Hempstead, Herts. RICHARD ARBIB.

Receiver Design

"DIALIST'S" paragraph in the October issue stating that he will be seeking a first-class v.h.f. receiver when f.m. transmissions commence in his area touches a very sore spot.

At an ever-increasing rate for the past three years there have appeared published designs, v.h.f. kits and sets for sale by the dozen, all with that primitive perpetration, continuous tuning. Two outstanding exceptions (both factory built) up to date enough to incorporate pre-set switched tuning prove that the difficulties are not insuperable. In these days of electronic miracles continuous tuning for the three locals is just not good enough.

When v.h.f. comes my way I shall have switch-tuning for the Third, Home and Light programmes, even if it means retaining my existing a.m. equipment.

Chasetown, Staffs. STANLEY MAY.

Technical Training

THE recent outcry at the lack of scientists and technicians prompts me to voice my own personal experiences in the almost impossible task of finding suitable technical instruction.

I endeavoured to study for the City and Guilds full technological certificate in telecommunication engineering. The nearest suitable institute is situated twenty miles away and necessitates a tedious two-hour journey to attend. I am, however, willing to undertake this for three evenings a week in order to attend classes.

When I approached the authorities three years ago I was informed that I must start at the beginning of the course even though my home study would see me through the first two years. Result: two wasted years sitting in classes writing elementary notes that I knew from A to Z. Now, after having obtained at great waste of time the necessary slips of yellow paper for an intermediate certificate, I find I do not qualify as I haven't taken an elementary mathematics examination. This, of course, necessitates attending a suitable course before I am allowed to sit for the examination.

My enquiries for the third year course of instruction drew a complete blank. There were insufficient students enrolled to form a class. The alternative that I was offered was a five-year course leading to a Higher National Certificate in electrical engineering. But, I was informed, this would of course necessitate my starting at the beginning before I could sit for any of the examinations! Another two or three wasted years.

The alternative is, I suppose, the not very satisfactory correspondence course, the price of which, even on the instalment plan, is beyond my compass. Why not therefore relax the awkward rule that insists on attendance on a recognized course of instruction and let the "home study" students take their place in the examination room. The worst that they can do is fail.

I shall enquire again next year for the course that I desire to take, but I am certain what the answer will be. Meanwhile, when scanning the "Sits. Vac." columns I will continue to kick my heels in frustration through banging my head against the same old brick wall.

Does anyone want a good right arm in exchange for the rest of the course on which I have set my heart?

Faversham, Kent. S. J. COE.

Flywheel Sync

AS an engineer with a little experience of television it is inevitable that friends contemplating the purchase of a television receiver ask my advice. This has happened on numerous occasions since the opening of the Norwich transmitter and I have always confined any advice to expressing certain design features I personally would wish to be incorporated in the receiver. One such feature I always mention as being highly desirable is flywheel synchronization or horizontal a.f.c. But it appears I must be wrong. Or am I?

Without exception, the prospective customer has approached the dealer and immediately this feature is mentioned every argument against it has been brought forward; every possible reason imaginable being used to convince the now not-so-sure customer that flywheel sync is not only unnecessary, but even undesirable.

Can someone explain this apparent paradox?

Norwich. R. WILLIAMSON.

Print-through or Pre-echo ?

THE "pre-echo" which R. C. Bell has noticed (March issue) on some long-playing and standard discs is not due to print-through on the magnetic tapes used for the recording but is an inherent fault in the cutting of a disc.

As the groove is cut a small mound is formed on each side and this tends to displace the adjacent groove. In effect, any large-amplitude signal is superimposed, much attenuated, on to the previous groove.

The modern method of disc recording is to record as high a signal level as possible and as many records begin at a high level this "pre-echo" can be easily heard.

London, E.15. J. MOSS.

"*Loudspeaker Enclosure Design*"

I REFER to the second part of the article on this subject in *Wireless World*, February, 1956.

Since this enclosure is a bass reflex with an acoustical resistance loading the port, I must question the validity of the impedance curves on page 79. These curves and comments on page 77 purport to show that the upper resonance f_2 and the anti-resonance f_0 have been reduced to negligible proportions, whilst the lowest resonance f_1 remained virtually unchanged. That this is a physical impossibility can be readily seen by analysing the complete analogue of the system as shown in Fig. 12, page 77. The addition of an acoustical resistance of proportions such that the impedance peak at f_2 becomes reduced to negligible proportions would completely eliminate the impedance peak at f_1 regardless of the values of the port mass reactance and volume stiffness reactance.

The velocity in the port mesh and, therefore, radiation decreases rapidly as the resonant frequency f_2 is approached. Since the velocity in the port mesh would be greatest in the region of f_1, the addition of an acoustical resistance would have its greatest effect at f_1 and not at f_2. Mr. Jordan cannot validate his statements by claiming that the two resonances are interchanged with respect to those in a bass reflex design where f_0 is below the free-air resonance of the cone.

Since the lowest resonance is governed by the mass reactance of the port and the stiffness reactance of the cone suspension, it is impossible to interchange f_1 and f_2 regardless of the placement of f_0.

Jensen Manufacturing Company, J. F. NOVAK.
Chicago.

The author replies

I AM indebted to J. F. Novak for his remarks and regret that certain of my arguments may not have been perfectly clear. The following notes are offered to amend this:—

It is incorrect to say that the "Axiom" enclosures are of the bass reflex variety with an acoustical resistance loading the port. The port is formed by the small opening in the centre of the resistive material in the "Acoustical Resistance Unit." This port contains no acoustical resistance other than the viscous resistance that occurs at its edges. The resistive material should be considered as being quite separate from the port, the two being combined in the "Acoustical Resistance Unit" only for practical convenience. I would like to stress that when referring to the port I am not referring to the relatively large aperture into which the "Acoustical Resistance Unit" fits. The "Axiom" enclosure is not a bass reflex enclosure since, by definition, we understand the latter to be an enclosure which will change the phase of the radiation from the rear of the cone and emit it as *useful radiation* from a port having dimensions comparable to those of the loudspeaker cone. Further, for optimum results, it is usual to arrange for the resonant frequency of a bass reflex enclosure to coincide with the free-air resonance of the cone, thereby providing maximum damping at this frequency. The "Axiom" enclosures do not conform to either of these requirements.

Mr. Novak states that it is physically impossible to reduce the amplitude of the upper resonance to a greater extent than the lower resonance f_1. The mechanism of this is fully described on pages 77 and 78 of the February issue, and may be summarized in the following way. Let f_0 be the resonant frequency of the parallel section only. Below f_0 this section behaves as a mass reactance and above f_0 as a stiffness reactance, which added to the series section will produce the two resonances f_1 and f_2 respectively. Now if we make the resonance of the parallel section only (f_0) occur at a higher frequency than that of the series only (free-air cone resonance), then it can be seen from Fig. 13 that the reactance of an f_2 is much higher than an f_1. Since R_f is in parallel with the reactance due to the enclosure, the Q of this will be lower at f_2 than at f_1. The text takes this a stage further and, by translating the effective parallel section into an equivalent series circuit, gives simple proof that the total circuit Q at f_2 may be considerably less than at f_1.

The second argument against Mr. Novak's statement that this is a physical impossibility may be found in the fact that it works, and may readily be shown to do so not only by measurements on an enclosure but also by measurements on an actual electrical circuit made to conform to Fig. 12.

In the second part of his letter Mr. Novak states that the velocity in the port would be greatest in the region of f_1. This is not true since the maximum velocity at the port of any vented enclosure occurs at the resonant frequency of the enclosure. Bearing in mind that the port is the actual open area in the centre of the A.R.U., maximum velocity occurs in this opening at f_0. If we incorrectly regard the entire aperture containing the A.R.U. as the port, then maximum velocity would occur here at some very much higher frequency (i.e., higher than f_0). Maximum velocity could not possibly occur anywhere near the frequency f_1 since this is below f_0.

I do not understand Mr. Novak's remarks regarding the interchange of the two resonances. I have not claimed that this happens and I agree that it does not. So far as I can see this is irrelevant.

Goodmans Industries, Limited, E. J. JORDAN.
Wembley.

REPRODUCTION FROM

MAGNETIC TAPE RECORDS

Playback Requirements for Single-channel and "Stereosonic" Tapes

By M. B. MARTIN,* A.M. Brit. I.R.E., and D. L. A. SMITH,* B.Sc. (Eng.), A.M. Brit. I.R.E.

THE development by Electric & Musical Industries, Ltd., of a practical method of making commercial copies of their original master tape recordings opened up new possibilities in the field of very high quality music reproduction.

These single-channel tape records were the forerunners of the fundamental new development of the "Stereosonic" technique of recording and reproduction first announced by "His Master's Voice" in April, 1955.[1] These tape records add a new dimension to recorded and reproduced music, giving a sense of depth, perspective and movement which is not present in single-channel reproduction.

The purpose of this article is to offer some guidance to those who as yet may have had little experience of these records, in the hope that a few pitfalls can be avoided in the design and construction of reproducing equipment.

The standards to which tape records are made have been published;[2] the main factors involved for reproduction purposes are speed, track dimensions and frequency characteristic. The track dimensions are given in Fig. 1: a track of 0.110in is recorded on each half of a tape 0.250in wide; in the same figure the recommended replay track width of 0.090in is also shown. The reason for this difference of 0.020in is to prevent modulation of the reproduction by scanning the edge of the recording. The tape speed is 7½in/sec, which speed enables a very nigh standard of reproduction to be obtained with a playing time from a standard 7-in diameter reel, equal to that of a long-playing disc record.

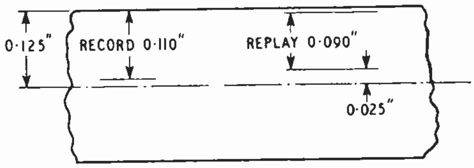


Fig. 1. Track dimensions for half-track recordings.

The recordings are so made that when played with the active side of the tape away from the observer and the tape passing from left to right, the upper track should be scanned.

The frequency characteristic has been defined as conforming to that preferred by the Comité Consultatif International des Radiocommunications (C.C.I.R.) for programme interchange. For a tape speed of 7½in/sec this is defined as a bass rise equivalent to that of a series combination of resistance and capacitance with a time constant of 100 μsec, together with high-frequency lift to compensate for replay head losses.

The distortion content of a tape record is extremely low when compared with the output from a gramophone pickup; it is indeed comparable with that of many amplifiers. At peak signal level the harmonic distortion content is about 2 per cent, but a signal 3 dB below peak has a distortion content of 0.4 per cent and at 6 dB down, 0.1 per cent. A curve of distortion against recording level is given in Fig. 2. Even if the recording is occasionally allowed to overload, the result is not as distressing to the ear as is the distortion produced by the excessive levels sometimes found on modern disc records.

The dynamic range of tape records is high and to do them justice a reproducer should have a signal/noise ratio which approaches 60 dB.

The foregoing remarks apply to both single-channel and "Stereosonic" tape records, but with the latter, both recorded tracks are replayed together. The track dimensions are as given above, and when replayed with the tape passing from left to right with the active side away from the observer and the recording in the correct sense, the top track should be reproduced through the left-hand speaker and bottom track through the right-hand. The tracks are so recorded that the reproducing head gaps should be accurately in line: that is the gap of the top track replay head must be *vertically* above that of the bottom head. This point will be taken up further when we deal with heads in detail.

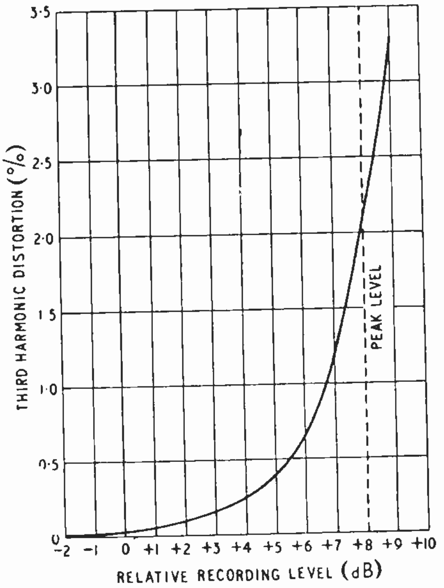


Fig. 2. Distortion plotted against recording level for a high-coercivity tape.

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* E.M.I Sales and Service, Ltd.

[1] *Wireless World*, May 1955, p. 202.

[2] *Wireless World*, October 1954, p. 512.

The results obtained when reproducing tape records depend to a very large degree upon the performance of the tape transport mechanism. The three main aspects of this are the speed constancy, spooling performance and the arrangement of the guides and pressure pads.

Speed Variation. The wow and flutter produced by a suitable mechanism should be no greater than that of a first-class transcription-type turntable. That is, the r.m.s. total wow and flutter should be no worse than 0.2 per cent, and preferably better than 0.1 per cent. Unfortunately, tape decks giving a genuine performance of this order at a price which might be considered reasonable for a domestic machine appear to be scarce. The prospective buyer of a given deck is advised to judge for himself by a careful listening test whether the wow and flutter performance will be acceptable to him.

We must also take account of the mean speed measured over a short period—a few seconds to tens of seconds, such as would be indicated stroboscopically or by timing a short tape-run—as distinguished from the overall mean speed, which is simply the quotient of

$$\frac{\text{Full length of tape on spool (inches)}}{\text{Time for complete play (seconds)}}$$

The short-term mean speed of most tape machines varies somewhat from one end of a spool to the other. This variation should not be more than ±1 per cent of the overall mean speed, which in turn should not differ from the nominal speed by more than ±1.5 per cent.

Spooling. The tape as spooled by the machine should be evenly wound, no turns of tape should have risen above or fallen below the general level, and the reel of tape should not touch the spool cheeks on either side. The tape tension during the spooling operation should be high enough to enable the wound tape to support itself on the hub alone, be firm enough to be handled without difficulty, even if dropped on a table from the height of a few inches, and be able to resist attempts to push it off the hub. This requirement is most important when the tapes are to be stored for long periods. Again, the tape tension should not be so high that the tape is stretched, as will happen if enthusiasm to achieve the performance laid down above is carried too far. A satisfactory tape tension during the spooling operation is between 80 and 90 gm, for a normal thickness (0.0023in) tape on which the records are made.

The brakes should bring the tape to rest in a minimum time of one second and a maximum of two seconds, without causing the tape to jump or ride out of the guides (or break!). After having been stopped, the tape should be taut, but not excessively so.

The Tape Run.—The tape guides in the tape run over the head and pinch wheel, etc., should be positioned accurately to ensure that the tape lies correctly on the head and that it winds on to the spools symmetrically between the spool flanges. When the tape is running over the heads and guides there must be no tendency for the tape to deform in any way, and there must be no vibration or oscillation of the tape.

Heads.—It should be understood that two replay heads of the same nominal inductance and front gap dimensions, but of different constructions, will in general have different frequency (and sensitivity) characteristics. The "quality" of the front gap, its depth, its relation to the back gap, the iron losses, self-capacitance loss and the condition of the working face must all affect the head's performance; consequently, it is essential to regard a particular manufacturer's head and an associated amplifier as a unit.

For a given tape speed, the ultimate frequency response of the unit depends on the replay head, with the front gap thereof as the most important factor. The edges of the gap must be straight, clearly defined and parallel, whilst the working face of the head should have had imparted to it a high surface finish without impairing the definition of the gap. If, for a tape speed of 7½ in/sec, a response level to 12 kc/s is aimed at, the magnetically-effective length of the replay gap will be about 0.0003in. Anything much greater than this may well lead to trouble with instability of the equalizing amplifier, and in any case will yield a high level of hiss when replaying. As stated earlier, the track width to be scanned is 0.090in; the head should therefore have a "stack" height equal to this.

The laminations should be carefully insulated from each other, and be as thin as possible, in order to reduce high-frequency losses. 0.005in thick Permalloy C is a suitable lamination material, provided that it is carefully and correctly annealed. The dimensions of the working face must be carefully chosen in order to prevent wavelength interference effects in the bass. The principle here is to profile the head in relation to the arc of the tape contact so that the extremes of the arc are not sharply defined. The response obtained with a poor head from this point of view is shown in Fig. 3.

The impedance of a replay head is a matter of some importance. A high-impedance head (about 500 mH inductance or greater) has the advantage that no input transformer is required. Another factor to be taken into consideration is that the self-resonance frequency of the head and input circuit is usually within the frequency range of the machine. This resonance can be used to aid in equalizing for the high-frequency losses, but it is a practice which cannot be recommended, as the variation of inductance from head to head and of stray capacitance of amplifiers will make any attempt at reproducing the results from an experimental amplifier a nearly impossible task. A better system, in any case, is to use a low-impedance head (inductance, a few millihenries) in conjunction with an input transformer.

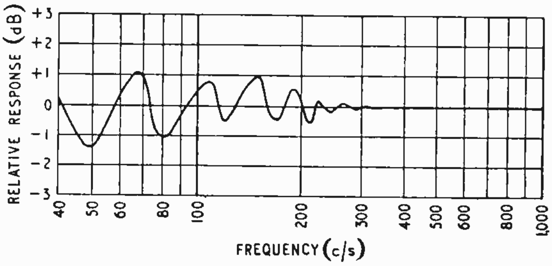


Fig. 3. Replay response from tape, including head, showing interference phenomenon. Tape speed: 7½in/sec. Tape with constant current in head. Replay output equalized for normal 6dB/octave rise.

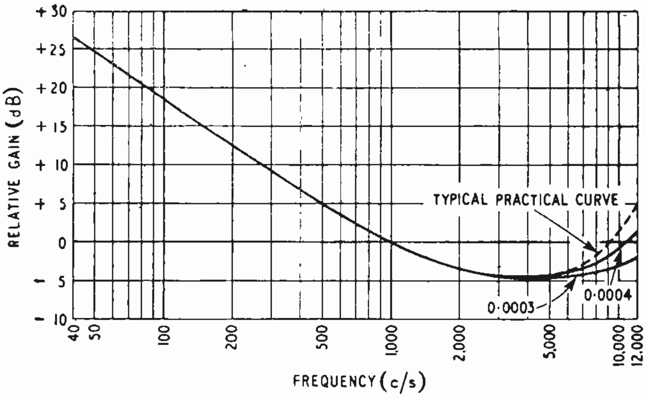


Fig. 4. Replay chain response, 7½in/sec (100 μsec + gap loss).

If the transformer is placed very close to the input grid, the capacitance troubles are minimized and an astatically-wound transformer needs the minimum of screening in order to minimize hum. With a balanced primary winding and a tightly-twisted pair of leads from the head to the transformer, the hum troubles in the primary circuit are small.

The following specification applies to a replay head designed for stereophonic working. It can be regarded as the minimum standard required in order to realize full advantage from both the "Stereosonic" and single-channel tape records.

Mechanical

Track width	0.090in	+0.005in −0.0025in
Track separation	0.050in	+0.0005in −0.000in

Max. permissible lateral gap displacement 0.0005in

Performance

Frequency response (measured at 7½ in/sec with constant record current in a separate record head using a bias amplitude adjusted for maximum playback voltage at 1 kc/s). Playback loss at 12 kc/s relative to playback voltage at 1 kc/s to be not more than −12 dB, allowance being made for record head losses.

Balance between tracks

Sensitivity at 1 kc/s: playback voltage from each track to agree within ±1 dB.

Frequency response: playback voltage at 12 kc/s relative to playback voltage at 1 kc/s to agree within ±1 dB.

Front gap alignment: when the azimuth is adjusted for maximum output from one track at 12 kc/s the loss due to misalignment of the second track to be less than 1 dB at 12 kc/s.

Cross talk

When replaying a half-track recording at 2 per cent distortion level (track spacing 0.030in), the cross-talk generated in the head section scanning the unrecorded track to be less than −50 dB at 10 kc/s.

The comparatively high figure of cross-talk rejection is not necessary for satisfactory "Stereosonic" reproduction, about 35 dB would be sufficient; however, the machine should be capable of playing single-channel tape records, and for this purpose −50 dB cross-talk is just satisfactory (60 dB rejection is necessary if full use is to be made of the dynamic range of the tape). The 60 dB degree of rejection is extremely difficult to achieve in the head alone, whilst a figure of 55 dB can be reached only by rather unconventional head construction and multiple, inter-track screens of Mumetal and copper.

Amplifiers

The requirements of a pre-amplifier for tape records are low noise and hum levels, low distortion, and careful equalizer design. These requirements are no different from those of any other pre-amplifier, but the signal at the first grid is unlikely to be in excess of 10 mV at 1 kc/s; thus a signal-to-hum ratio of 60 dB involves very careful design. With the 100 μsec bass rise, the lift between 1 kc/s and 50 c/s is nearly 25 dB, hence the signal available at 50 c/s is about 600 μV, and to achieve 60 dB signal-to-noise ratio the equivalent hum at the grid of the first stage can be no greater than 0.6 μV, which implies the use of a hum-bucking arrangement, even when the input valve is of the Z729 type.

The curves in Fig. 4 give typical pre-amplifier responses for heads with effective replay gaps of 0.004in and 0.0003in. The precise amplifier response in the high-frequency region depends also upon the head losses other than the gap loss. That is, the curves of Fig. 4 indicate the minimum h.f. response required for heads of the quoted effective gaps. A typical working curve is shown as a dotted line. Final adjustment of response is most readily carried out by playing a standard frequency test tape. It will also be found that the low-frequency output from certain types of replay head is somewhat (one or two dB) greater than would be expected if the l.f. output is assumed to be proportional to frequency.

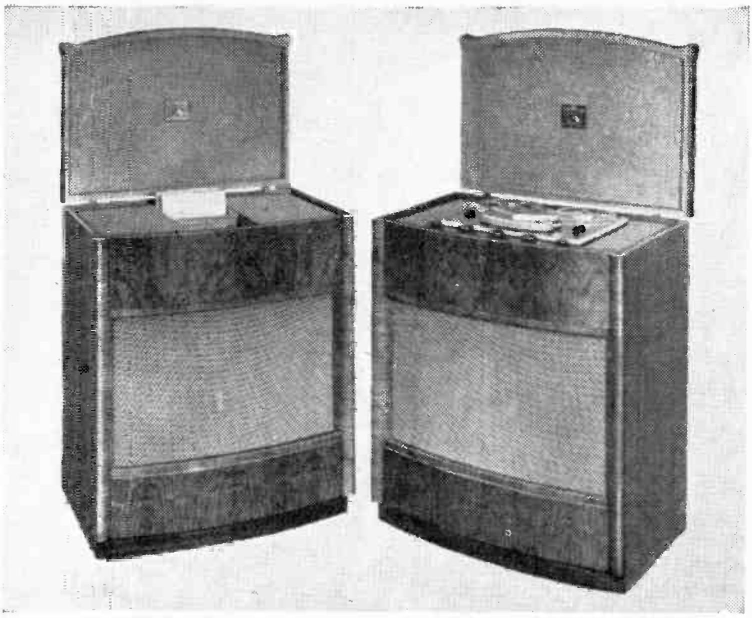
The amplifier should be so designed that there is no danger of oscillation at the peak frequency of the equalizer lift and that the non-linear distortion introduced by the method of lifting is negligible.

For "Stereosonic" reproduction, it is advisable that the gains of the pre-amplifiers should be individually variable to enable the residual differences in head sensitivity and amplifier gains to be removed in the setting-up process. The high-frequency equalizers should be variable so that the slight difference in head responses can be accounted for. It is also an advantage if the output stage is a cathode follower or some other low-impedance circuit, in order that power amplifiers can be fed through unequal lengths of cable if necessary, without the risk of the magnitudes of the outputs becoming unbalanced or of hum pick-up taking place.

The power amplifiers should introduce very little distortion, a figure of 0.25 per cent max. is typical, and the frequency range at full rated power should be 30 c/s to 12 or 15 kc/s. For "Stereosonic" equipment, the gains of the power amplifiers should be accurately matched: a satisfactory method of achieving this is to use a high degree of feedback with close-tolerance high-stability resistors in the feedback loop. A gain match of less than 0.5 dB is necessary and can be achieved in this way.

In both power and pre-amplifiers, care should be taken to avoid uncontrolled phase shifts within the working frequency range. Tone and gain controls, etc., should produce identical effects in both channels. For convenience in operation, such controls may be ganged. However, the resistance/rotation laws of a normal commercial-grade potentiometer are not claimed to be matched to within the 5 per cent required by a twin-channel system. The preferred arrangement is the use of switched controls with the resistance elements if possible of a high-stability type.

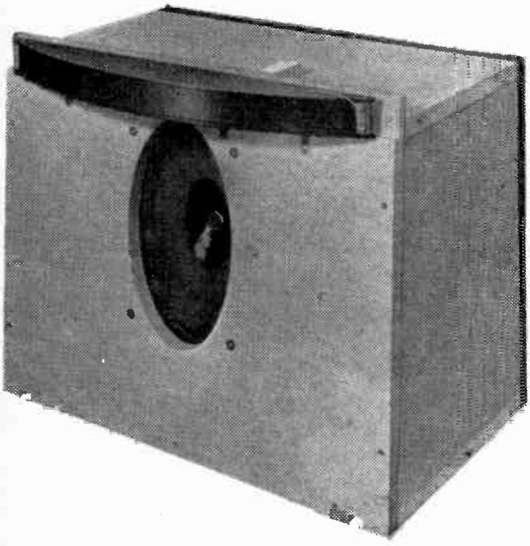
In some rooms, it may be necessary to correct electrically for acoustic unbalance, which causes a lateral shift of the sound image. Adequate correction can be made by raising the gain of one channel relative to the other. For a permanent installation, this can be done "once-and-for-all" when the equipment is set up. Otherwise, a differential gain control between channels should be provided.



H.M.V. Model 3034 "Stereosonic" reproducing equipment in its latest form.

"Stereosonic" Reproducers

The final result from a "Stereosonic" reproducer can be spoilt by a careless choice of loudspeakers, however carefully the amplifiers and head are designed and made. The loudspeakers used should have closely matched responses and sensitivities. If one loudspeaker has a peak at say 8 kc/s which is absent from the other, this can have the distressing effect of divorcing a singer's voice from its sibilants. The singer then appears to be standing in the centre, say, with all the sibilance appearing to come from a point a foot or two away! The polar diagram of the loudspeakers should ideally be as nearly semicircular in the horizontal plane as possible. Fortunately, the advent of electrostatic loudspeakers has helped considerably at the high frequencies. The "beamed top" often associated with high-quality loudspeakers can cause a distinct loss in the effective sound image when compared with a speaker with an even distribution.



Loudspeaker assembly comprising an elliptical moving-coil and a high-frequency electrostatic unit.

It may also be found to be an advantage if the back radiation of the loudspeaker is limited. In certain types of room the acoustic loading of the room on the backs of the bass speaker cones can cause unbalance in the low-frequency end. Fortunately, the majority of high-quality bass enclosures have very little back radiation.

Our experiments have shown that a high standard of "Stereosonic" reproduction can readily be achieved in domestic conditions, from rooms as small as 9ft × 11ft to the baronial hall; in fact, we have not yet found a domestic type of room in which good results cannot be readily obtained.

These experiments were carried out using the prototype of the Model 3034 H.M.V. "Stereosonic" reproducer, which has been designed according to the principles outlined. The pre-amplifiers have pre-set gain controls variable over about 6 dB to facilitate the balancing procedure, and the equalizers are variable as outlined above. The volume, bass and treble controls are ganged; they are step controls using high stability resistors, the volume control being graded in ten steps; the difference in gain between the two channels on any position of the controls is not greater than 0.5 dB. The other two controls on the top panel are a system switch giving "Stereosonic," "Single-channel tape," a "Single-channel auxiliary" input and the "Balance" control; this is a differential gain control (in the single-channel positions the inputs to the two power amplifiers are in parallel). On the rear of the control console there is a switch which reverses the two channel feeds to the loudspeakers, so that the control console can be placed on either side of the second cabinet.

In the photograph of a loudspeaker unit the long bowed electrostatic speaker which operates from 5 kc/s upwards can be seen at the top. The bass unit is an elliptical speaker enclosed in an airtight box of 3.5 cu ft, the system being critically damped with a system resonance between 45 and 50 c/s (on an open baffle the speaker resonance is 22 c/s). The power amplifier driving this loudspeaker system is push-pull, delivering 10 watts to the bass unit, with a side amplifier delivering 140 V r.m.s. to the electrostatic speaker. There is an overall negative feedback loop of 26 dB, the resistors in this loop being high stability type with a close tolerance in order to ensure that the gain of all production amplifiers is held within 0.5 dB of standard. The frequency response of the system is unusually smooth from 40 c/s to 16 kc/s, with a polar response which is substantially semi-circular up to 10 kc/s; the deviations above this frequency are slight.

In conclusion, we would say that given the necessary recordings, "Stereosonic" reproduction is not as difficult as it may sound, provided that the choice of heads, loudspeakers and amplifiers is made with the factors mentioned above in mind.

Finally, the authors would like to thank the British Institution of Radio Engineers for permission to use much information which was contained in a paper presented by the authors to the Institution on 5th January, 1956, and published in the —*Journal Brit.I.R.E.*, Vol. 16, No. 2, February, 1956.

Frequency Stabilization of Oscillators

By V. N. GRAY, B.Sc.,*

Negative Temperature Coefficient Capacitors as Correcting Elements

IT is well known that the frequency of an oscillator changes with temperature and that it can cause distortion and loss of signal strength in an f.m. or television receiver.

The inductance of a coil varies with temperature; this is brought about by dimensional changes and also to changes in the current distribution in the wire. The latter is caused by variations in skin and proximity effects as the wire resistance changes. Dimensional changes with temperature depend on a number of factors. If a coil could be freely suspended, its temperature coefficient would be the same as the temperature coefficient or linear expansion of the wire. Since the coil must have fairly rigid connections, even if not suspended by other means, mechanical strains cause added changes in dimensions so that the resultant temperature coefficient may be several times that of the linear expansion of the wire. The contribution to the temperature coefficient due to resistance changes is small at low and very high frequencies when the skin and proximity effects are respectively small and very large. At frequencies of the order used in v.h.f. broadcasting and television where skin and proximity effects are moderate, the temperature coefficient of resistance of the wire has its greatest effect. Thus an accepted value for the temperature coefficient of inductance of an open-wound coil is of the order of +120 parts per million per degree centigrade. When the coil is wound on a former, such as in an i.f. transformer, this value may be reduced to about +100 p.p.m. per °C.

The temperature coefficient of capacitance for a silvered mica capacitor may vary from zero to about +60 p.p.m. per °C, this being almost entirely due to change in dimensions. Values up to +150 p.p.m. per °C have been quoted for the temperature coefficient of air-dielectric trimmer capacitors, caused by linear expansions of the plates, bending of the plates due to different linear expansions of different parts of the assembly, and deformations due to residual stress changes.

The stray capacitance has a temperature coefficient of similar order to that of an air-dielectric trimmer, so that in the oscillator circuit of a v.h.f. receiver, where the tuning capacitance usually consists of stray capacitance and a trimmer, the resultant temperature coefficient is of the order of +150 p.p.m. per °C, while in an i.f. circuit it would be about +100 p.p.m. per °C.

Let us take the case of a Band II f.m. receiver, operating at approximately 90 Mc/s. If the oscillator were on the high side, its frequency would be approximately 100 Mc/s. (The usual value for the intermediate frequency is 10.7 Mc/s.)

In the oscillator circuit the combination of capacitance and inductance change may, in the worst cases, amount to +270 p.p.m./°C which corresponds to a frequency change of −140 p.p.m./°C:—

Using $f = \dfrac{1}{2\pi\sqrt{LC}}$

The new frequency f'

$$= \frac{1}{2\pi\sqrt{[LC\,(1+150\times10^{-6})\,(1+120\times10^{-6})]}}$$

$$= \frac{1}{2\pi\sqrt{[LC\,(1+270\times10^{-6}+\ldots.)]}}$$

neglecting the last term in the expansion.

Then

$$f-f' = \frac{1}{2\pi\sqrt{LC}} \times \left[1-\sqrt{\frac{1}{1.00027}}\right]$$

$$\approx \frac{1}{2\pi\sqrt{LC}} \times 0.00014.$$

This would mean a frequency change of −140 × 100 c/s, i.e. −14 kc/s, in the oscillator for each °C change in temperature. Over an extreme range, from the "cold set/cold room" conditions (10°C) to "warm set/warm room" state (40° C), the frequency drift is thus −30 × 14 kc/s, i.e. −420 kc/s.

Likewise, an i.f. circuit, having temperature coefficients of inductance of +100 p.p.m./°C and of capacitance of about +50 p.p.m./°C (correspond-

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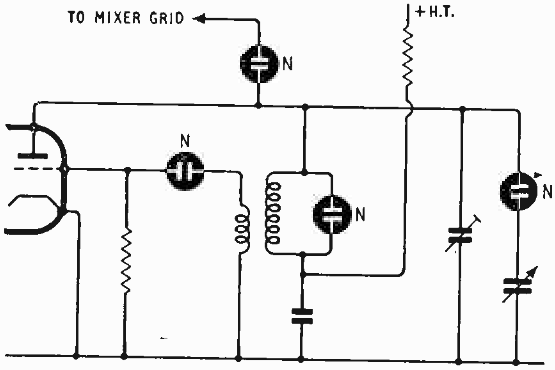
*A. H. Hunt (Capacitors) Ltd.



Some of the positions in an oscillator circuit where a negative-temperature-coefficient capacitor might be used are shown here marked " N." One or two positions only so equipped might serve in some cases.

ing to a temperature coefficient of -75 p.p.m./°C), will drift $-30\times75\times10$ c/s, i.e., $-22{,}500$ c/s approximately. Since this change is in the same direction as the change in oscillator frequency, the overall difference in tuning frequencies between the two conditions is some 400 kc/s. When this figure is compared with the 180 kc/s bandwidth for the i.f. channel of an f.m. receiver, it may easily be appreciated that severe distortion will occur due to non-operation of the limiter and incorrect operation of the discriminator (or ratio detector), even if the signal is not completely lost during the warming-up period.

Fortunately this effect may be overcome by the use of negative-temperature coefficient capacitors. There is generally no point in putting a correction capacitor in both oscillator and i.f. circuits and it is usual to design the oscillator circuit to have approximately the same drift as the i.f. amplifier. In the case we have cited, the oscillator circuit should be arranged to have a small negative-temperature drift of $\frac{22.5}{30}$ kc/s/°C; i.e., a coefficient of $\frac{22.5\times10^3}{30\times100}$ p.p.m./°C, which is $+7.5$ p.p.m./°C. The LC product must, therefore, have a final coefficient of $+15$ p.p.m./°C. (If the oscillator frequency were below the signal frequency these signs would be reversed.) Since we quoted a temperature coefficient of inductance of $+120$ p.p.m./°C for the inductance, the capacitors (including strays) must have a temperature coefficient of -105 p.p.m./°C. If the total capacitance in the circuit (including valve and other strays) is C and the negative coefficient part (of say -750 p.p.m./°C) is c then

$$-105\,C = -750\,c + 150\,(C - c)$$

$$c = \frac{255}{900}\,C$$

$$= 0.283\,C.$$

Values for the " accessible " capacitance in oscillator circuits for typical (including home-constructed) receivers vary from about 25 pF upwards, depending, naturally on the coil and the type of circuit used.

Since the lowest value capacitor having a negative-temperature coefficient of 750 p.p.m./°C usually quoted by manufacturers is 10 pF, it would seem that a total circuit capacitance (including strays) of some 35 pF is indicated. This is not an unreasonably large value, but since the values for temperature coefficients quoted above are likely to be on the upper limit of those encountered in practice, it might become necessary to use the correction capacitor across a part only of the coil.

Another possibility might be to use the negative-temperature-coefficient capacitor as the whole, or part of, the coupling capacitor to the valve, thereby putting it in series with a high proportion of the stray capacitance, so that the temperature coefficient of the combination becomes negative in the right proportion to compensate for the remainder of the circuit. One point, which would have to be watched here, is that the oscillator must then have plenty of drive in hand. Such an arrangement used with a circuit which is only just oscillating might cause the oscillations to cease when the value of the coupling capacitor falls with temperature rise! Some of the positions in an oscillator circuit where a negative-temperature capacitor might be used for frequency stabilization are indicated by an " N " in the accompanying circuit diagram.

Naturally this capacitor should be mounted where its temperature is likely to be an average between the coil temperatures and the temperature attained by the valveholder and other strays. Again it should not be fitted close to a wirewound resistor or other heat-dissipating element, nor near a hole in the chassis, where local draughts, hot or cold, could affect its temperature rise considerably.

He would indeed be a lucky person who managed to find the right value for the correction capacitor and its right position first time, because local temperature variations, uncertainty of true temperature coefficients of stray capacities and a tolerance in the temperature coefficient of the correction capacitors, all tend to work against the experimenter. For those people, however, who would have a life of ease in not having to retune their receivers after the warming-up period, or those who aspire to push-button tuning on v.h.f. receivers, some simple experiments are indicated.

Naturally, these experiments are likely to be a little tedious if perfection is to be attained, due to the temperature and time cycles involved, but the fitting of a suitable value correction capacitor, deduced as above, should take care of most of the drift. It is important, if a trial is made, that the receiver should be completely reassembled, even to the back of the cabinet being fitted, as otherwise one cannot be sure that true warm-working conditions are achieved. Again, if the first trial is not too successful, the experimenter should note whether the necessary retuning is still in the same direction, as over-correction is possible.

"TRADER" YEAR BOOK

A VALUABLE new feature of the 1956 edition of the "Wireless and Electrical Trader Year Book" is a very comprehensive table of television receiver i.fs. and side-band characteristics of superhet and t.r.f. models. Other features include a list of i.fs. of sound receivers marketed in the past eight years; condensed specifications of nearly 250 current television receivers and over 400 sound receivers; and base diagrams and connections for some 300 current valves and c.r. tubes. The usual directories of manufacturers, wholesalers, trade names and a buyers' guide are also to be found within the 344 pages of the Trader Year Book. Published by the Trader Publishing Co., Ltd., Dorset House, Stamford Street, London, S.E.1, it costs 12s 6d (postage 1s).

FURTHER NOTES ON THE

Simplified Band III Convertor

CONSTRUCTIONAL DETAILS OF FIXED-TUNED AERIAL FILTER

By O. E. DZIERZYNSKI

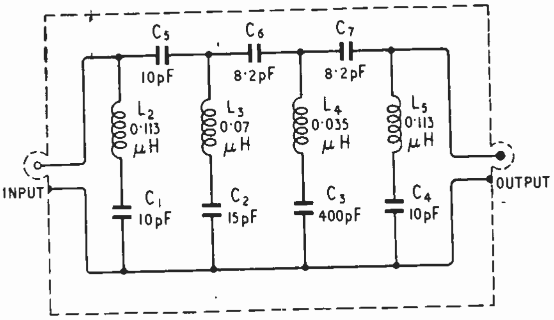


Fig. 1. Theoretical circuit diagram of the fixed-tuned Band III aerial filter. Coil numbers are the same as in the original tunable filter; capacitor numbers are different.

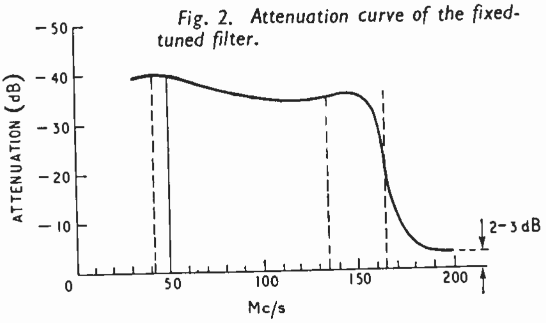


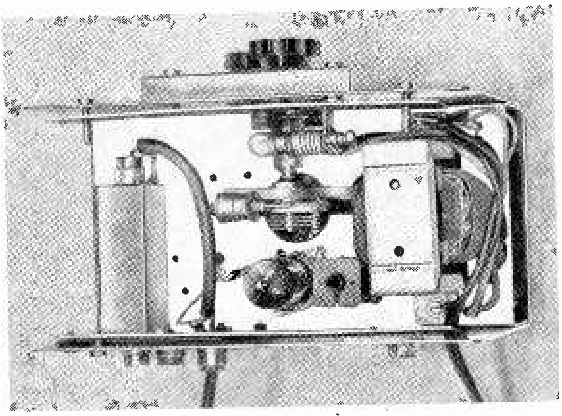
Fig. 2. Attenuation curve of the fixed-tuned filter.

At the end of the article in the March issue describing the Simplified Band III Convertor it was stated that work was in hand on a new aerial filter which would require no alignment. This was to be achieved by using fixed values of inductance and fixed capacitors. The new filter is now completed and is shown here in the illustrations and its circuit, which is theoretically the same as that used for the original tunable filter, is repeated for convenience in Fig. 1. The only significant differences are slightly modified capacitor values to bring them, where practicable, to the 10% tolerance preferred values. The coil numbering is the same as the original and so an L_1 will not be found in this article. It was not practicable to retain the same capacitor numbering.

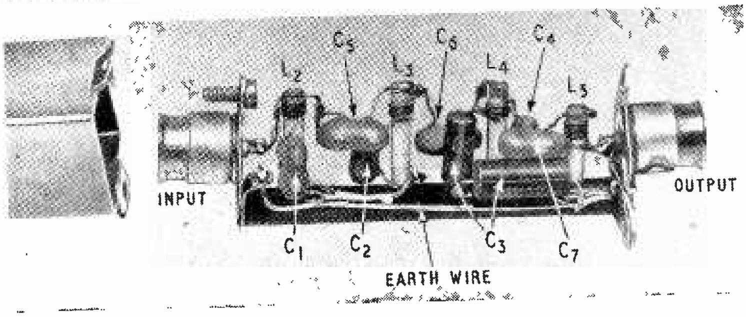
Physically the filter is quite different, the fixed-tuned filter being built into a screening case measuring only ¾in square by 2⅜in high. This miniaturization, as it might be called, may tax the skill of some potential constructors but any trouble entailed will be well repaid as no precise measurements or adjustments are involved and, furthermore, the new filter has an appreciably better performance than the old.

A comparison of the new one's response curve, Fig. 2, with that of the original's (Fig. 4 on page 136 in the March issue) reveals that the attenuation of the new model is maintained reasonably constant at between −35 and −40 dB up to about 150 Mc/s, whereas the earlier model's curve exhibited a marked dip between 50 and 100 Mc/s. The improved performance results from the all-round reduction in size of the filter; miniature capacitors have been used and as they comprise the bulk of the wiring all connecting leads are consequently very much shorter.

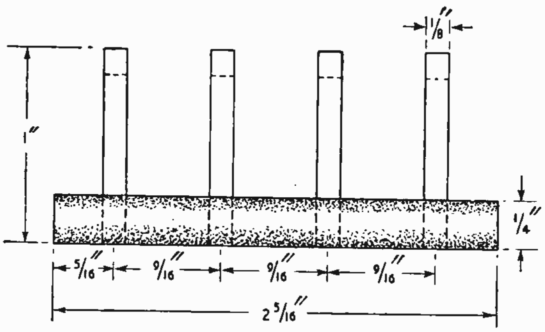
In order to reproduce the performance close



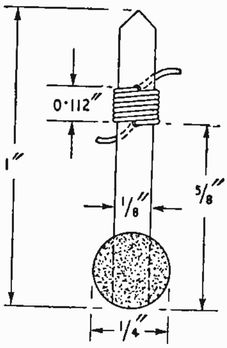
The new filter fitted inside the convertor.



The fixed-tuned filter removed from its can; the annotation conforms to Fig. 1 and enables all components to be identified.



Above: Fig. 3. Spacing of the coil supports on the "backbone" rod of the filter.



Left: Fig. 4. Constructional details of the coils.

adherence to the form of construction shown here is essential. The position and diameter of the coil supports are critical and so is the actual position of the windings on the coil supports.

The filter is assembled on a ¼-in diameter rod of rigid insulating material, such as ebonite, Paxoline, or Erinoid to mention a few suitable materials, and the four coils, L$_2$ to L$_5$, are wound on ⅛-in diameter plastic rods (Polystyrene or Nylon) inserted into tightly fitting holes in the ¼-in rod, or "backbone," and spaced along it as shown in Fig. 3.

Winding data for the four coils is given in the coil table and all coils are wound in the same direction with No. 32 s.w.g. enamelled wire and with adjacent turns touching. Each coil should start ⅝in up from the base of the former, as shown in Fig. 4, and the ends of the winding threaded through 1/64-in diameter holes with about ½in projecting from the opposite side of the coil support to serve as connecting points for the capacitors.

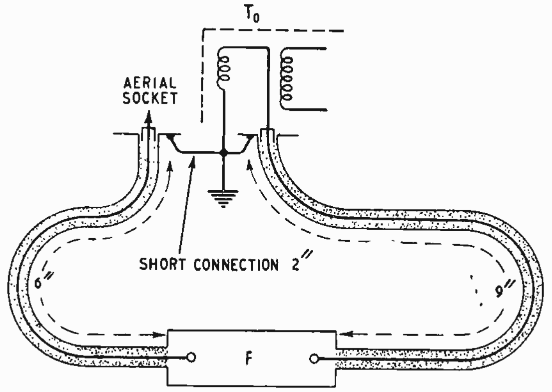


Fig. 5. Method of arranging connecting cables when the filter is fitted inside the convertor.

COIL TABLE

Coil	Inductance (μH)	Turns (close wound)	Wire (s.w.g.)	Winding length (in)
L$_2$ and L$_5$	0.113	7	No. 32 En	0.112
L$_3$ ..	0.07	5¼	do.	0.094
L$_4$ ..	0.035	3¼	do.	0.055

Miniature capacitors must be used in the filter and they can be ceramic, polystyrene or metallized paper types. All, except the largest, C$_3$, must be under ½in long and not more than 3/16in in diameter, because if they are much larger it will be difficult to pack them into the confined space of the small screening case. The essential thing is that the capacitances be as stated here, the make of capacitor is not important.

The 400-pF capacitor, C$_3$, while shown in Fig. 1 as a single capacitor, is actually two capacitors connected in series. This value is not a preferred value and so had to be made up by connecting a 500-pF capacitor in series with one of 2,000 pF. If a 400-pF capacitor of a small enough size can be found it will simplify the construction.

In the illustrations both ends of the filter are shown fitted with coaxial sockets and they are secured by 6-BA screws inserted into tapped holes in the ends of the main support, or "backbone." Before fitting the filter in its can the small centre hole usually found in the top of most ¾-in square coil cans must be enlarged to about ½in in order to enable the sleeve of the input coaxial socket, which is the one at the top of the can, to pass through. In addition, two 6-BA clearance holes have to be drilled in the top of the can, on a diagonal and corresponding to the fixing holes in the coaxial socket. A 6-BA screw is soldered into one of the base holes in the socket with its head pointing inwards and the shank outwards so that when the filter is fitted into its can the shank of the screw passes through one of the holes in the top of the can and is secured by a nut and washer. The other 6-BA hole should be in line with the other hole in the socket, and also with the tapped hole in the end of the "backbone," and through all three is inserted a 6-BA screw which, when tightened, securely clamps filter, socket and can together.

From the foregoing it will, perhaps, have been gathered that the filter is inserted in the screening can with the "backbone" support resting in one corner and the coil formers projecting diagonally across the can. In order to prevent any likelihood of the filter's wiring "earthing" to the inside of the can (except where intentional, i.e., at the input and output ends), the inside of the can should either be coated with a good insulating varnish or protected by a strip of thin insulating material.

There is an "earth" wire running alongside the "backbone" to which the "earthy" ends of capacitors C$_1$, C$_2$, C$_3$ and C$_4$ are joined and this is terminated at each end by soldering to one of the fixing lugs on the base of the coaxial sockets.

The output socket, which is located at the bottom when the filter is inserted in the can, is secured to the "backbone" by a 6-BA screw. This screw holds in position also a short strip of brass, or aluminium, in which is drilled a 6-BA hole at each end. These holes are located so that when the socket is screwed to the "backbone" the hole at the free end of the strip coincides with the hole in the fixing lug of the screening can. The other hole in the coaxial socket's base should align with the other fixing lug on the screening can.

The coaxial sockets admittedly complicate the construction of the filter and in certain cases they could be omitted. The sockets are fitted mainly to enable the filter to be used as a separate unit external to any Band-III convertor and inserted in the aerial feeder if break-through of Band-I signals is affecting the Band-III picture. This must not be confused, however, with direct pick-up of signals on the convertor's wiring, as an external filter will obviously not cure this particular form of television interference.

If the filter is to be used solely, or at least initially, with the Simplified Band-III Convertor the two coaxial sockets can be omitted and replaced by the appropriate lengths of 75-ohm coaxial cable terminated at their free ends with coaxial plugs if so desired. The input cable has to be 6in long if a short rod aerial is employed, otherwise any convenient length can be used to join the filter to the aerial coaxial socket on the convertor. The output of the filter must always be connected to the input transformer (T_6 Fig. 2, page 134, March issue) by a 9-in length of coaxial cable. When the filter is housed inside the convertor these pieces of cable can be disposed of as shown in Fig. 5.

I.T.A. Midlands Relay

POST OFFICE RADIO LINK TO LICHFIELD TELEVISION STATION

WHEN a new television transmitting station such as Lichfield or the new I.T.A. Yorkshire station, scheduled for later in the year, is opened, it is the responsibility of the Post Office to transmit the vision and sound signals from the I.T.A. programme switching centre to the transmitter with no noticeable deterioration in quality and with a high standard of reliability.

A network of Post Office coaxial cable trunk circuits serves the Midland Area B.B.C. stations but such a network when fully loaded cannot readily be extended to carry additional programmes and it may then be of advantage to provide a radio system in one of the frequency bands recommended at the Atlantic City Convention for fixed point-to-point communication links.

The Post Office has successfully operated a radio-relay system using v.h.f. frequencies of about 200 Mc/s, but restrictions in frequency space due to the growing demand by other services for further allocations in this part of the spectrum, and the fact that broad-band signals are more readily accommodated at higher frequencies, have encouraged the use of centimetric waves.

No broad-band radio-relay system for television operating above 4,200 Mc/s has yet been put into service in the U.K. The Post Office television links to Kirk O' Shotts, Isle of Wight, Aberdeen, Norwich and Lichfield have used frequencies of the order of 2,000 Mc/s or 4,000 Mc/s, and these will also be used for further links for both B.B.C. and I.T.A. services and for broad-band multi-channel telephony links forming part of the trunk network.

Factors which are related directly or indirectly to the frequency of operation are the attenuation of the radio propagation path and its susceptibility to fading, the gain of aerials of a given size, the characteristics of aerial feeders, the available transmitter power and receiver noise factor. Future systems planned for the same route or area have also to be considered before deciding on the frequencies to be used on a specific link. However, despite the variety of factors involved and the widely differing techniques employed, both 2,000 Mc/s and 4,000 Mc/s systems have been developed to meet exacting requirements for performance and reliability laid down by the Post Office, and in general no clear advantage can be demonstrated by either over the other.

The Lichfield station, which lies about 12 miles to the north-east of Birmingham, is served by two television channels from Telephone House, Birmingham, to Lichfield and one return channel, on frequencies of 1,712 Mc/s, 1,784 Mc/s and 2,216 Mc/s respectively. Although the path length is comparatively short, it has been necessary, in order to obtain a radio path unobstructed by high buildings in the city, to erect the Birmingham aerial, an 8 ft diameter, spun-aluminium paraboloid reflector, about 30 ft above the roof of Telephone House and 133 ft above street level. At Lichfield a 12 ft diameter reflector is mounted at a height of about 140 ft from ground level on the I.T.A. station mast.

Aerial Characteristics

At 2,000 Mc/s the aerial gains relative to an isotropic radiator are approximately 31 and 34.5 dB and the beam width about 5° and 3° at the half-power points for 8 ft and 12 ft diameter aerials respectively. The three channels share a single aerial at each terminal. This is a very desirable feature in view of the possibility of the wind loading on a large paraboloid reflector reaching several tons in a gale. A rigid tower structure is necessary to prevent deflection of the relatively narrow radio beam, and additional aerials would complicate the problem and increase the cost of the towers which represent a substantial item in the total cost of the link. The r.f. multiplexing of three channels on each aerial is achieved by using horizontal and vertical polarization for the two directions of transmission and combining two channels on one type of polarization by means of an r.f. channel dropping, or combining, unit referred to later. The reflector is excited from a waveguide launching unit at the focus. This comprises a section of waveguide short-circuited at one end and containing two probes mounted in space quadrature. Each probe is fed by a helical membrane feeder cable of 75 ohms characteristic impedance, pressurized with dry air. Two types of cable are available with attenuations of 1.75 dB or 2.6 dB/100 ft at 2,000 Mc/s.

Frequency modulation is adopted as it has the advantages over amplitude modulation of allowing the linearity requirements of the overall performance to be more easily met, and of a higher video signal-to-noise ratio. The latter arises from the characteristic "triangular" noise distribution associated with frequency modulation, i.e., a noise-power per unit bandwidth that increases with increase of video frequency at 6 dB/octave, a higher noise being tolerable in a television signal at higher video frequencies.

The peak-to-peak deviation employed is 7 Mc/s, and the bandwidth occupied by the transmitted signal at peak deviation about 14 Mc/s. Each transmitter and receiver comprises two racks of equipment of the type shown in Fig. 1.

At the transmitting terminal the incoming video signal, after amplification and d.c. restoration, is applied to a modulator which delivers a frequency modulated output signal at a mean frequency of 60 Mc/s and with full deviation.

An a.f.c. system associated with the modulator ensures that the frequency corresponding to the bottom of the synchronizing pulse is stabilized, and operates by the comparison of the modulator signal frequency during synchronizing pulses, with the cross-over frequency of a discriminator circuit. A bias is developed proportional to the difference between these frequencies and is applied to the modulator in a sense that tends to reduce the difference.

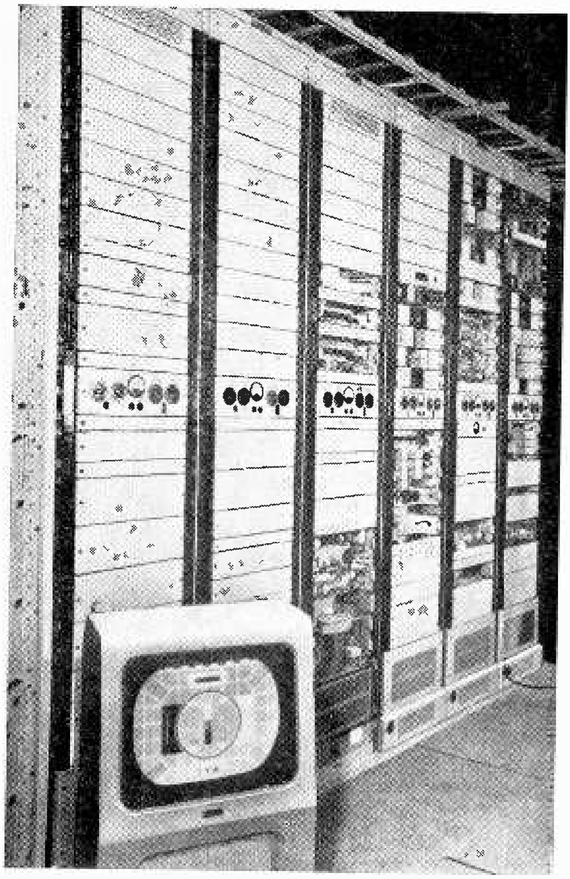


Fig. 1. Two terminal receivers and one transmitter at the Lichfield end of the Post Office 2,000-Mc/s radio link.

The modulated 60-Mc/s signal is amplified in several stages of wideband amplification and applied to a u.h.f. frequency changer. The u.h.f. stages comprise a frequency changer, an oscillator and three amplifiers; disc-seal triodes are used in each stage, designed to function as an integral part of two concentric line anode-grid and grid-cathode circuits each tuned to resonance at the appropriate number of quarter-wavelengths by non-contact bridges. Loops and adjustable probes coupled to these circuits provide means for injecting or extracting signals.

The frequency of the u.h.f. oscillator is stabilized within 60 kc/s by a reference cavity the resonance frequency of which is frequently modulated over ±0.7 Mc/s at 50 c/s by a small metal disc rotated by a synchronous motor at 1,500 r.p.m. A crystal detector is coupled to the field within the cavity, the 100-c/s modulation component is filtered out and, if the cavity frequency differs from the oscillator frequency, a fundamental 50-c/s component is present which represents in amplitude and phase the extent and sense of the frequency difference; this component is selected and used to control an induction motor which mechanically resets the anode circuit tuning bridge.

The final amplifier stage comprises two u.h.f. 1-watt amplifiers operating in the circuit shown in Fig. 2. This circuit includes two coaxial line hybrid rings and the principle of their use as a ring mixer has been described in *Wireless World*, March, 1954, page 139. In this application of the circuit freedom from troublesome feeder and aerial echo effects is ensured and a better impedance match to the feeder is obtained than is practicable with a conventional output circuit. The hybrid rings are connected by two line sections of equal length in each of which is an amplifier. By mutual displacement of the amplifiers in the line sections and by tuning of their output circuits above and below the carrier frequency the outputs of the amplifiers provide a mismatch to the lines which present conjugate impedances at points 1 and 2. Echo or reflected signals returning at point 3 will divide in the arms of the ring and combine at point 4 to be dissipated in the resistive load. The amplifier output signals are in phase at the aerial feeder connection but in antiphase at the load. The final amplifier stage comprising the two disc-seal triode valves in coaxial line circuits and a coaxial line hybrid ring is shown in Fig. 3.

The hybrid ring circuit is also used as a channel combining or dropping filter, serving to multiplex r.f. channels on a common aerial, by substitution of appropriate band-stop filters for the amplifiers in the circuit shown.

A superheterodyne receiver is used comprising a silicon crystal frequency changer, u.h.f. local oscillator, low-noise pre-amplifier and main i.f. amplifier, limiters, a two-tuned-circuit or Round-Travis discriminator and video amplifier. By careful design of the input stages of the receiver a noise factor of 15 dB is achieved.

Under free-space propagation conditions there is a loss of about 124 dB in the Birmingham-Lichfield radio path, which is relatively short, the average being about 30 miles for u.h.f. and s.h.f. television links. However, the need for long aerial feeders at both terminals, for channel dropping filters and the use of a small aerial at one terminal result in a carrier level at the input to the receiver frequency changer of not more than 100 millimicrowatts, which is somewhat less than would be expected on a path of average length.

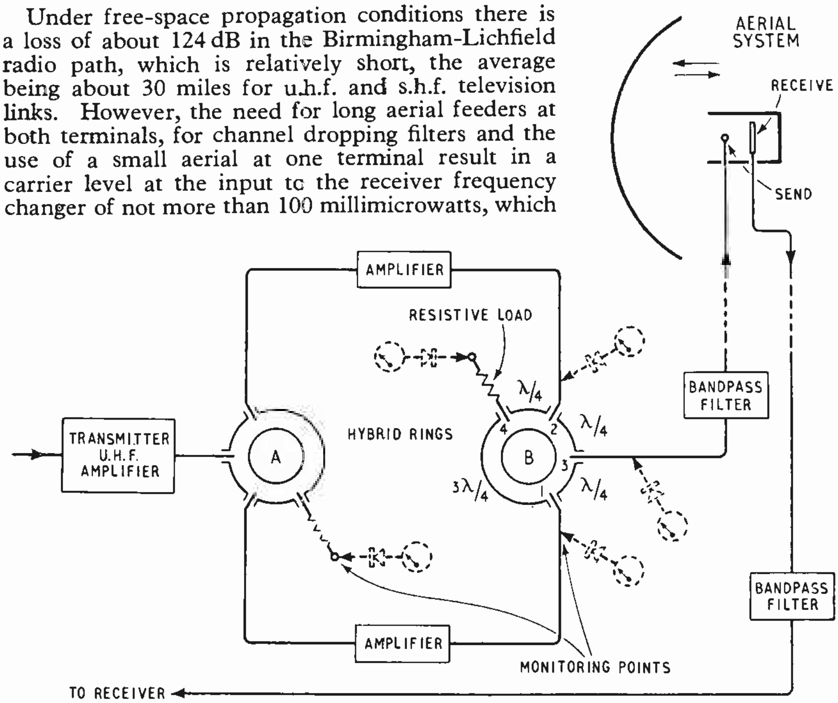


Fig. 2. Hybrid ring circuits are used in the final amplifier stage of the 2,000-Mc/s transmitter.

The pre-amplifier of the receiver comprises seven stages, of which the first two are low-noise earthed-grid triodes. The pre-amplifier and main i.f. amplifier are tuned as "staggered triples" in which one stage is tuned near the mid-band frequency and two other stages are tuned above and below this frequency. The bandwidth is 16 Mc/s at −3 dB points. Automatic-gain-control action on both amplifiers maintains the output level constant within 3 dB for variations from the normal input level of +10 dB to −20 dB. An adequate margin in overall signal-to-noise ratio allows for much deeper fading than is likely to be experienced on this link.

The specification for the radio equipment has to allow for the variety of design techniques offered by different manufacturers, and is therefore primarily a statement of a required overall transmission performance in terms of signal-to-noise ratio, attenuation-frequency, phase-frequency and linearity characteristics, waveform response at low frequencies, transient response to a step-waveform, stability of gain, etc. Ideal free-space propagation conditions are assumed and it is the responsibility of the Post Office to ensure that fading, site noise and reflections from obstacles such as buildings do not degrade the performance below an acceptable limit. The performance of a short path in these respects may be estimated sufficiently accurately from a map and site survey, but if long or difficult paths are involved the Post Office undertakes propagation tests on site on a long-term basis if necessary.

The testing of television links, either initially on completion or for routine purposes, can be a somewhat involved procedure and improvements in testing techniques are continually being sought and introduced. The trend is for the tedious investigation of steady-state responses to be largely replaced by a rapid check of a complex waveform designed to provide much of the information previously obtained.

In order to serve the Lichfield transmitter from London, as well as from Birmingham, an extension of the system to Birmingham Telephone House from the Post Office distribution centre for television circuits in the Museum Telephone Exchange Building in London is necessary. Here the main line or radio-link circuits to and from Birmingham and the North, Wenvoe, St. Margarets Bay and the Isle of Wight terminate in a television control room together with numerous short-tie studio circuits used to connect places of interest in the London area with the B.B.C. switching centre at Lime Grove, or with I.T.A. switching centres at Television House or Foley Street. The London-Birmingham link used is that which was originally brought into service in 1949

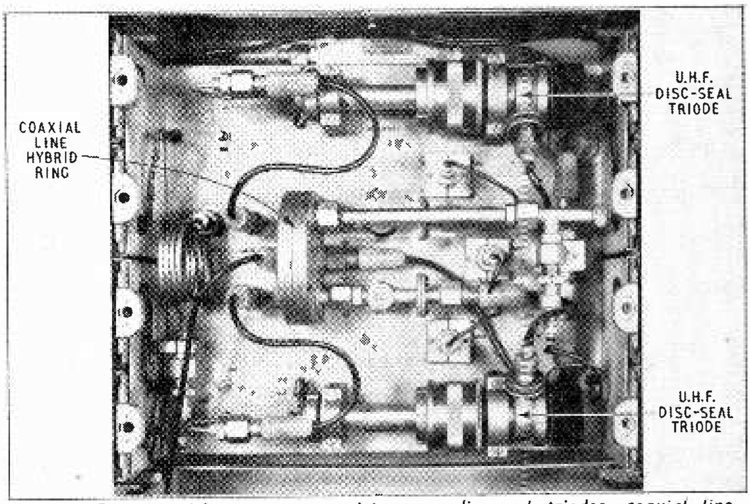


Fig. 3. Final amplifier stage comprising two disc-seal triodes, coaxial line circuits and hybrid ring.

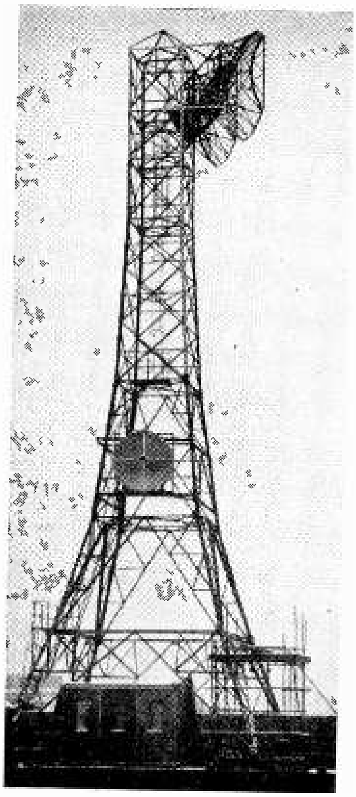


Fig. 4. Tower supporting u.h.f. aerials on the roof of the Birmingham Telephone House.

for the opening of the B.B.C. television transmitter at Sutton Coldfield and was the first radio-relay link to be used for television relaying purposes. Since 1950 this service has been provided mainly by coaxial cable circuits. The radio link includes four intermediate stations and in order to obtain line-of-sight paths over 40 miles in length the route makes good use of natural land contours, and the intermediate repeater stations are situated on the Elstree ridge north of London, the Chiltern Hills, the Cotswold Hills and the high ground to the west of Birmingham. The link has recently been modified slightly in design in order to conform with current performance specifications but differs from later links in several important features; the radio equipment is housed in cabins at the top of towers, a practice that has not since been repeated; valves are operated in parallel in most stages, a safeguard which is no longer considered necessary; instead of a solid surface the paraboloidal reflectors are formed from parallel tubes spaced approximately one quarter-wavelength apart with provision for heating the tubes to prevent an accumulation of ice. In over six years' operational experience of this link, however, no case has been recorded of the necessity for aerial de-icing. Fig. 4 shows the tower on the roof of the Telephone House, Birmingham, with aerials for the u.h.f. radio links to London and to Lichfield.

As new techniques are introduced so additional specialized training has to be given to the Post Office technicians who maintain the links. The equipment is designed for unattended operation, but it is necessarily so complex that only by the unremitting efforts of an efficient maintenance organization, carrying out frequent routine tests and analyses of faults, is it possible to achieve those standards of performance and reliability which are characteristic of the television relaying network now operating in this country.

Acknowledgment and thanks for some of the information contained in this article are due to the General Electric Co., Ltd., who manufactured and installed the London-Birmingham and Birmingham-Lichfield radio-relay links.

COMMERCIAL LITERATURE

Silver Rivets for contacts; new low-cost design using silver facing on copper backing, with tubular shanks to simplify riveting operation and avoid stresses on contact supports. Descriptive leaflet from Johnson, Matthey and Co., 73-83, Hatton Garden, London, E.C.1.

Aerial Wall Chart, giving quick reference (with diagrams) to television and v.h.f. aerials for Bands I, II and III made by Aerialite, of Castle Works, Stalybridge, Cheshire.

Tungsten and Molybdenum Wires for use in the manufacture of valves and lamps. Catalogue giving diameters, weights and other physical data from Mullard, Raw Materials Division, Century House, Shaftesbury Avenue, London, W.C.2.

Phase Sequence Indicator for showing correct or incorrect phase sequence in 3-phase a.c. mains supplies with voltages varying from 5 to 500V and frequencies between 5 and 1500 c/s. Uses rectifiers working back-to-back. Literature from the Electrical Instrument Co. (Hillington), Glasgow, S.W.2.

Band-III Stacked Aerial Arrays, composite Band-I/Band-III aerials (indoor and outdoor types), and an adaptor kit to enable f.m. sound transmissions to be picked up on television aerials. Leaflets from Antiference, Bicester Road, Aylesbury, Bucks.

Disc and Tape Recorders, direct-recording discs, magnetic tape, amplifiers, pickups and cutter-heads. Leaflets describing all their products from the M.S.S. Recording Company, Poyle Farm, Colnbrook, Bucks.

Television Distribution System, covering 13 channels, for blocks of flats, hotels, hospitals and other large buildings. Leaflet from Pye, P.O. Box 49, Cambridge.

Digital Frequency Meter, covering 10 c/s to 30 Mc/s, working on a gating and counting principle with crystal-controlled time intervals. Megacycles are read on a calibrated dial and kc/s and c/s on a digital indicator with 6 decades (up to 999,999 c/s). The accuracy is ±1 count. Descriptive leaflet from Racal Engineering, Western Road, Bracknell, Berks.

Echo Sounder Simulator is now available for training fishermen to operate the Kelvin Hughes "Kingfisher" echo sounder. Leaflet describing the "Kingfisher" itself (using electrolytic recorder and c.r.t. viewing unit) from Kelvin and Hughes (Marine), 99 Fenchurch Street, London, E.C.3.

Nickel Alloys, as used in valves for r.f. heating, in strip-wound cores for inductors and transformers, and in long-life valves for submarine repeaters. Well-written articles in "Wiggin Nickel Alloys," No. 39, from Henry Wiggin and Company, Wiggin Street, Birmingham, 16.

Components and Accessories; a May, 1956, illustrated catalogue from Radiospares, 4-8, Maple Street, London, W.1.

Solder Wires, solid and resin-cored; solder paints, liquid fluxes, solder preforms and other products listed in a catalogue from Enthoven Solders, 89, Upper Thames Street, London, E.C.4.

Television Distribution System covering channels 6 to 13 with facilities for introducing f.m. signal. Uses cascode pre-amplifiers with cathode-follower output units giving outputs for 6, 36 or more receivers as required. Leaflet from the Rainbow Radio Manufacturing Co., Mincing Lane, Blackburn, Lancs.

Signal Generator, small servicing type, covering 150 kc/s to 220 Mc/s in six bands, with a continuously variable output attenuator and four-step decade multiplier giving maximum signals of 100 μV, 1 mV, 10 mV and 100 mV. Leaflet from The Automatic Coil Winder and Electrical Equipment Co., 92-96, Vauxhall Bridge Road, London, S.W.1. Also a leaflet describing a new range of tropicalized Avometers.

Silicone Rubber, notable for maintaining dielectric strength, dielectric constant and power factor throughout a wide temperature range (−50°C to 150°C); also for maintaining surface resistivity under conditions of high humidity. Electrical and other properties described in a booklet from the Dunlop Rubber Company, Cambridge Street, Manchester, 1.

Silica Gel Dessicant for protecting equipment against moisture. An illustrated brochure on methods of humidity protection and the applications of "Sorbsil" Silica Gel made by Joseph Crosfield and Sons, Warrington, Lancs.

Television Receiver Input Impedance

By J. E. HOPKINS,* B.Sc.

Formulæ for Use in Conjunction with Bridge Measurements

MEASUREMENTS of the input impedance of television receivers (on Band I) are usually made using an admittance bridge. When making these measurements it is convenient to connect the input terminals of the receiver to the bridge terminals by coaxial cable. Given below is an analysis of the measurements to be made and the application of well-known formulae to the problem. Three measurements only are required and from these the required input impedance can be calculated.

If the length of the connecting cable is small we can assume that the attenuation is negligible. For such a length of cable of characteristic impedance Z_0 and electrical length θ radians, terminated by an impedance Z_x, the input impedance Z_{in} is given by:—

$$Z_{in} = r_{in} + jx_{in} = Z_0 \frac{Z_x + Z_0 j \tan\theta}{Z_0 + Z_x j \tan\theta} \quad .. \quad (1)$$

For a short circuited line $Z_x = 0$ and equation (1) becomes:

$$Z_{sc} = Z_0 j \tan\theta \quad .. \quad .. \quad .. \quad .. \quad (2)$$

For an open-circuited line $Z_x = \infty$ and we may therefore write $Z_{oc} = \dfrac{Z_0}{j \tan\theta}$ .. .. .. (3)

Substituting equations (2) and (3) in equation (1) we have:

$$Z_{in} = \frac{Z_x + Z_{sc}}{1 + \dfrac{Z_x}{Z_{oc}}} \quad .. \quad .. \quad .. \quad (4)$$

Rearranging equation (4) we obtain a formula for Z_x in terms of Z_{oc}, Z_{sc} and Z_{in}, that is:

$$Z_x = \frac{Z_{in} - Z_{sc}}{1 - \dfrac{Z_{in}}{Z_{oc}}} \quad .. \quad .. \quad .. \quad (5)$$

We can now outline the three measurements to be made: (a) a measurement of the impedance of the cable open-circuited (Z_{oc}); now as the cable length is so small the resistive component is negligible compared with the reactive component, i.e., $Z_{oc} = j\,x_{oc}$; (b) a measurement of the impedance of the cable short-circuited (Z_{sc}); again the resistive component may be ignored and $Z_{sc} = j\,x_{sc}$; (c) a measurement with the unknown impedance connected to the cable ($Z_{in} = r_{in} + j\,x_{in}$). We can now write equation (5) in a more convenient form thus:

$$Z_x = r_x + j\,x_x = \frac{r_{in}\,x_{oc}\,(x_{oc} - x_{sc})}{r_{in}^2 + (x_{oc} - x_{in})^2} + j\,\frac{x_{oc}\,x_{in}(x_{oc} + x_{sc}) - x_{sc}x_{oc}^2 - x_{oc}(r_{in}^2 + x_{in}^2)}{r_{in}^2 + (x_{oc} - x_{in})^2}$$

$$.. \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad (6)$$

Results from the admittance bridge give Z_{in} in the form of an admittance (G) in parallel with a capacitance (C). This must be converted to a series form in order to use equation (6), i.e., a resistance $r\left(=\dfrac{G}{G^2 + \omega^2C^2}\right)$ and a reactance $x\left(=\dfrac{\omega C}{G^2 + \omega^2C^2}\right)$

If it is necessary to convert from the series form to the parallel form then

$$R_p = \frac{r_s^2 + x_s^2}{r_s} \text{ and } x_p = \frac{r_s^2 + x_s^2}{x_s}$$

When using equation (6) it is essential that for measurements (a) and (b) the resistive component may be ignored when compared to the reactive component; to this end the cable used is made very short or, more suitably, cut to a length of approximately half a wavelength.

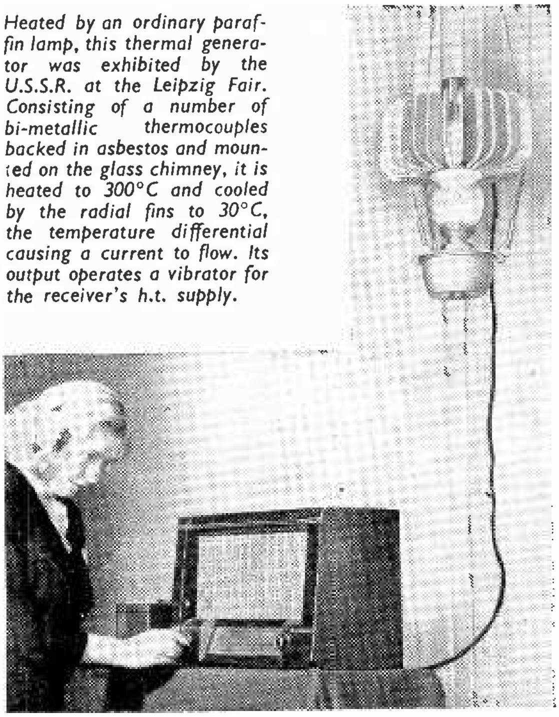
Incidentally multiplying equation (2) by equation (3), we obtain:

$$Z_{sc} \,.\, Z_{oc} + Z_0^2 \quad .. \quad .. \quad .. \quad .. \quad (7)$$

giving $Z_0 = \sqrt{Z_{sc} \,.\, Z_{oc}}$ .. .. .. (8)

Thus we have a useful method of finding the characteristic impedance, Z_0, of a length of cable.

THERMO-ELECTRIC RECEIVER



Heated by an ordinary paraffin lamp, this thermal generator was exhibited by the U.S.S.R. at the Leipzig Fair. Consisting of a number of bi-metallic thermocouples backed in asbestos and mounted on the glass chimney, it is heated to 300°C and cooled by the radial fins to 30°C, the temperature differential causing a current to flow. Its output operates a vibrator for the receiver's h.t. supply.

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* Ferguson Radio Corporation

Monitoring Sound Broadcast

EVOLUTION OF PRESENT METHODS OF ASSESSING QUALITY

By T. SOMERVILLE, B.Sc., M.I.E.E., F.Inst.P.*

TO ensure a satisfactory service to the listeners, broadcasting organizations have to monitor carefully all programme material. This monitoring, of course, extends not only to the technical standards of a broadcast but also to its programme content. In this article, however, discussion will be restricted to the technical standards of the audio-frequency signal leaving the studios. The reasons for monitoring are to detect technical faults and to allow the "balance" of the programme to be adjusted. Defects of a technical nature should obviously be removed, and for this purpose a broadcasting organization must be able to detect any faults which are likely to trouble listeners. "Balancing" an orchestra implies the placing of the microphone with respect to the performers to give the best balance between the various instruments as well as the best tonal quality. The question of balance is therefore more subject to controversy. It is necessarily largely a matter of opinion and personal preference, but is also influenced by the types of loudspeaker and microphone used and by the acoustics of the studio. This will be discussed later.

In establishing technical standards it must not be forgotten that the acoustic environment of the listener should be borne in mind, whether he is a listener at home or one of the monitors in the broadcasting organization. It is often argued that the standard used for monitoring should be that of the "average" listener and that it is unfair to employ standards to satisfy listeners who have provided themselves with better equipment and listening conditions. In practice this is not so. Most receiver manufacturers when testing a new design will endeavour to obtain the best results from the programme material being radiated by the B.B.C. There is therefore a desirable incentive to raise the general standards of technical quality if the B.B.C. maintains its standards at a level higher than that of the majority of current receiving equipment.

In the early days of broadcasting most of the studio and transmitting apparatus was experimental and it was some time before properly engineered equipment began to come into service. The listeners' equipment was even more rudimentary than that used in the studio and remained so for some time. Progress in the development of broadcasting equipment was steady, so that by 1930 a high standard of studio and transmitting apparatus had been reached. The development of receivers was more gradual but, even so, by 1939 a reasonable standard had been obtained, although only the most expensive receiving equipment could match the standards of the transmitting equipment. Hitherto it is mainly in loudspeaker design that progress has been lacking, so that even expensive receivers of what is called the "high-fidelity" type often have inferior loudspeakers. Since the war there have been gratifying developments in the loudspeaker field, but the standard of home equipment still lags behind the studio apparatus.

Not all the developments in audio-frequency systems can be attributed to the influence of broadcasting. The gramophone industry has done much in recent years to stimulate the development of better equipment by the production of disc and tape recordings having a wide frequency range.

Although the major developments in high-quality receiving apparatus have taken place since 1945, it was possible before 1939 to obtain loudspeakers which covered a wide range of frequencies. None of these was used for monitoring by the B.B.C. but, nevertheless, B.B.C. loudspeakers were better than those in the average commercial receiver. It should be realized that in B.B.C. practice every programme is monitored, first at the originating studio and subsequently at other points in the system before it is radiated from the transmitters. For this purpose it is necessary to have suitable loudspeakers and a suitable acoustic environment in which to listen to them. This environment should approximate to the acoustic conditions of a living room, and more will be said on this subject later. The loudspeaker should be good enough to enable the monitor to hear faults which might give trouble to listeners with good equipment, and if this requirement is satisfied there will be few justifiable complaints from the majority of listeners with ordinary commercial receivers. Soon after 1945 it became clear that many wide-range loudspeakers were becoming available and it therefore became necessary to select better monitoring loudspeakers for use throughout the broadcasting organization.

Loudspeakers.—The selection of a loudspeaker introduces quite unexpected difficulties. If several commercial loudspeakers are listened to on normal programme material it will often be found that the loudspeaker preferred depends on the programme material. This was found in the early tests on the subjective selection of wide-range loudspeakers. Such a situation is extremely unsatisfactory, since clearly it is not possible to use different loudspeakers for different types of programme. In an endeavour to find the cause of this anomaly, the loudspeakers were taken to a studio to enable a comparison to be made with the original programme. The studio was an orchestral studio. Here again the results were anomalous, because it was then observed that the loudspeaker preference depended upon the type of music being performed. At this stage it was noticed, while listening in the studio, that the orchestra itself sounded confused so that it was difficult to hear all the instruments.

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* Research Department, B.B.C.

† Complete diffusion implies uniform distribution of sound energy throughout an enclosure.

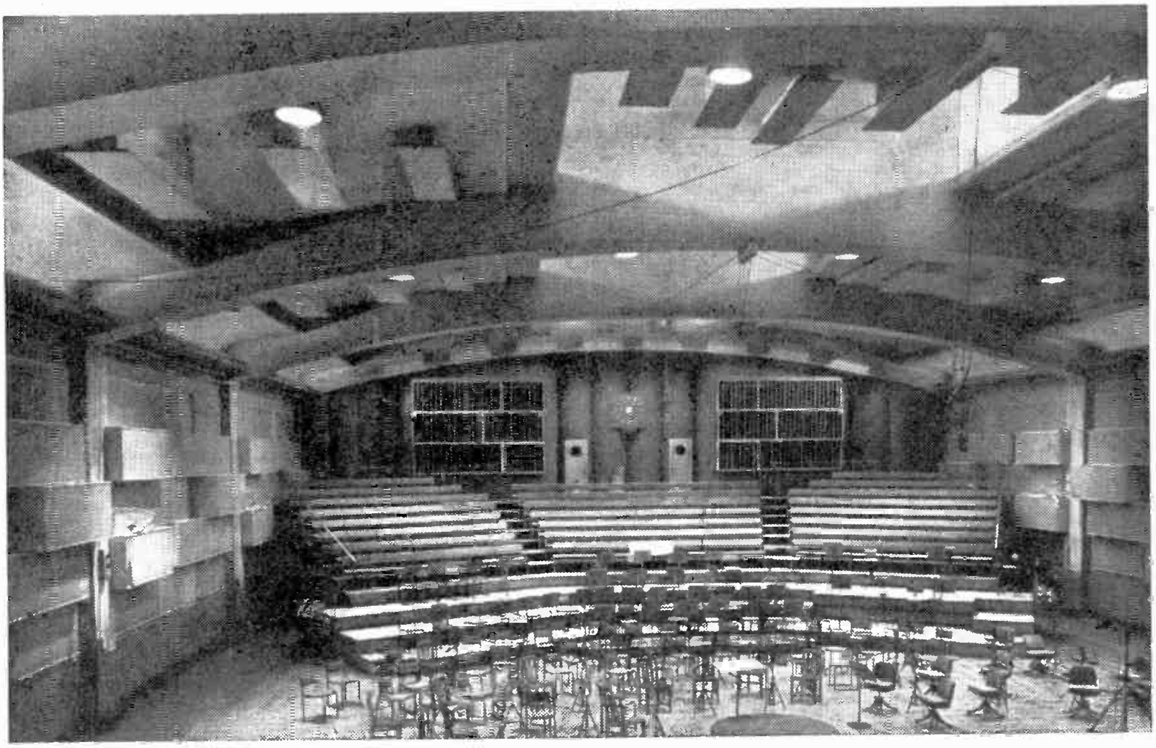
Programmes

As the acoustics of the studio were known to be poor it was considered that this fact might explain the anomalies.

Studio Acoustics.—Perhaps at this point it might be of interest to describe the way in which the acoustics of a studio can be assessed subjectively, merely by listening in the studio during a rehearsal. Although this may seem to be an over-simplification, it is a feat easily accomplished by a skilled listener without the aid of measuring equipment. With experience it is possible to assess the mean reverberation time approximately, to decide whether a studio is too reverberant or under-reverberant, and the frequencies at which colorations or other acoustic effects are noticeable. Diffusion† can be judged by moving about while listening with one ear. When diffusion is good the sound is distributed uniformly throughout the auditorium and there is little change in the ability to hear all the parts in an orchestral performance. Incidentally, this also means that the microphone position will not be critical. Listening with one ear only, it should also be possible to hear all the instruments even in very loud passages. If diffusion is poor and consequently the sound is not distributed uniformly, troublesome standing waves exist. Microphone positioning is therefore difficult and for the audience the interference patterns which accompany standing waves make the hearing of all parts in the music impossible. In addition poor diffusion results in sound dying away in an irregular fashion, thereby producing the subjective effect of hard tonal quality. Diffusion is normally achieved by having irregular surfaces on the walls and ceiling, which in the older concert halls took the form of baroque ornamentation or coffering. Fig. 1 shows the B.B.C. orchestral studio at Maida Vale in which can be seen the modern form of rectangular diffusing elements on walls and ceiling. If there are any large areas of panelling which resonate at a particular frequency this frequency will often be heard after the wanted sound has died away and the subjective result is called "coloration." The same method of selection applies to all studios, even talks studios, with the difference that it may be necessary to listen to the decay of tone to assess the acoustic performance, as music is not played in such studios.

Selection of Loudspeakers.—To check whether poor acoustics could indeed cause the difficulties experienced in selecting loudspeakers, the whole experiment was transferred to a good orchestral studio, where the consistent selection of loudspeakers was shown to be possible. Furthermore, it was found that the majority of commercial loudspeakers failed to give reasonable reproduction of the symphony orchestra used for the test; only three gave a satisfactory performance. Let us call these speakers A, B and C. At this juncture it was realized that, in making the selection tests, the balance had been carried out using a loudspeaker which was of type B. As this operation has to be accomplished by listening to a loudspeaker it is obvious that the type of loudspeaker may affect the result. The loudspeaker in the monitoring cubicle was therefore changed to type A to determine the effect of

Fig. 1. B.B.C.'s main orchestral studio at Maida Vale, showing rectangular diffusing elements on walls and ceiling.



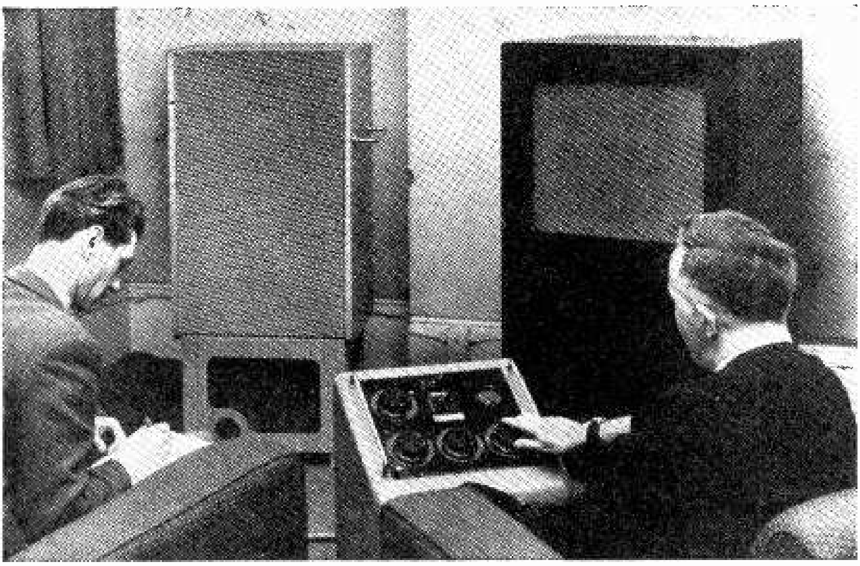


Fig. 2. Listening room in the B.B.C. Research Department. It has a reverberation time of 0.4 sec.

evolved. Measurements and listening tests eliminate all the worst examples, so that the final test need be applied only to those loudspeakers having a reasonable measured performance. The loudspeakers are placed behind a gauze curtain which is illuminated in front to prevent the panel of subjects from seeing the loudspeakers. The subjects are asked to say which unit gives the best reproduction of the original sound. In the case of speech, the speaker actually talks behind the screen as well as talking in a non-reverberant room with a microphone. For music, the tests are done at a studio centre where the subjects are at liberty to listen in the studio before giving their opinions.

the characteristics of the loudspeaker used for balancing, on the microphone position adopted. In re-balancing, the studio manager then moved the microphone to a more distant and higher position which gave extremely satisfactory results on loudspeakers A and C, increasing the perspective and sense of realism, and caused B to be rejected. It is interesting to note that loudspeakers A and B were single-cone units made by a well-known British manufacturer, and loudspeaker C was a wide-range American unit. It is also worthy of note that this was the first occasion on which satisfactory reproduction had been obtained on a wide-range loudspeaker; previously the results had always been hard, shrill and unpleasant. To complete the experiment, loudspeaker C was then used for monitoring, resulting in only a very slight change in microphone position from that found with loudspeaker A and still giving satisfactory results on both A and C but not on B.

In addition to tests such as that just described, it is obviously necessary to make tests on other programme material including speech. A speech test is one of the most exacting to which a loudspeaker can be subjected, since the human voice covers a very wide range of frequencies. If the speaker is known to the listeners, a very stringent test is possible. The speaker should be placed in a non-reverberant room or should speak out-of-doors to eliminate acoustic effects. Such a test is found to eliminate the majority of commercial loudspeakers.

Another factor in the subjective selection of loudspeakers which remains to be mentioned is the effect of the type of microphone employed for the tests. Fortunately microphone design has reached a stage at which most broadcasting microphones are much better in performance than any loudspeaker, so that for this type of loudspeaker test the effects of the microphone are not important.

Resulting from the early experiments, a technique for the subjective selection of loudspeakers has been

The final test, carried out in music studios only, with the loudspeakers concealed behind the screen, is to ask studio managers to balance the orchestra in turn with each of the loudspeakers under test, and to observe the resulting microphone positions. Loudspeakers with abnormalities will often cause the microphone position to be far removed from normal, while with very bad loudspeakers it is sometimes impossible to obtain a balance, using only one microphone. Although it is common practice to use more than one microphone to obtain special effects, particularly in variety and dance music, the introduction of so many variables into a loudspeaker test makes a valid comparison almost impossible. With many of the loudspeakers in commercial receivers, multi-microphone techniques would be necessary to achieve a good balance, and this balance would then be acceptable only if all listeners used loudspeakers with the same characteristics.

The tests described facilitate the introduction of improved loudspeakers which can be used for monitoring in the certain knowledge that the results will still be acceptable on older loudspeakers having a more restricted frequency range. This is an essential requirement because it is obviously uneconomic to replace all the loudspeakers in a large broadcasting organization at any given time. A progressive programme of replacement with continually improved loudspeakers is the only economic solution.

Microphones.—Similar methods of selection are applied to microphones. As loudspeakers improve it is possible to carry out experiments leading to better microphones and then return again to loudspeakers. Thus by improving successive parts of the chain it has been possible to raise the standards of broadcasting to a marked degree during the last ten years.

Listeners' Acoustic Environment.—It was mentioned earlier that a suitable environment is essential for the monitoring of broadcast programmes. In the B.B.C. the first approximation to this was to adjust listening rooms to have a reverberation time of 0.5 sec, a figure established by the Building Research Station as the average figure for a large selection of normal living rooms. For a number of years this reverberation time proved to be satisfactory; there is no doubt that for musical programmes the value is still suitable. Unfortunately, in the development of talks studios it became necessary to reduce the reverberation time to the region of 0.3 sec to remove colorations. It was then observed that faults in the acoustics of such talks studios could not be detected with any certainty in listening rooms with reverberation times of the order of 0.5 sec. This indicated the need for the reduction of the reverberation time of listening rooms, but before considering any changes a survey of living rooms was carried out. Measurements were made in a selection of living rooms, supplemented by listening tests consisting of the reproduction on a wide-range loudspeaker of a recording of well-known announcers speaking from a number of B.B.C. studios. Careful observations were made of the living room conditions under which it was possible to hear differences in studio acoustics. It was established that reverberation times in excess of 0.4 sec obscured the effects which monitors should hear in talks studios.

As a result of this investigation it is now B.B.C. practice to adjust its listening rooms to have a reverberation time of 0.4 sec. Fig. 2 is a photograph of the listening room in the B.B.C. Research Department which now has a reverberation time of 0.4 sec. Two loudspeakers are being compared. A further interesting conclusion from the tests was that the value of 0.4 sec often applies to well-furnished living rooms owned by listeners who can afford the better class of receiving equipment. It was also concluded that to reduce the reverberation time of listening rooms below 0.4 sec would be unrealistic because very few living rooms have values lower than this.

It is important to realize that it is only in the case of talks that the living room acoustics are important. For most other types of programme, reverberation times in the studios are much longer than 0.4 sec, and it is the studio reverberation which the listener hears—unless he listens in the bathroom.

Conclusions.—This survey of the methods of controlling broadcast quality shows that for studio monitoring it is not desirable to duplicate the conditions of the average home apart from the adjustment of the reverberation time of the listening room. The equipment used is at least as good as that employed by the most critical listeners. This policy has proved to be a wise one because, with the advent of frequency modulation and the great improvement possible in transmission and reception conditions, it is comparatively easy to provide satisfactory programme material without much change in broadcasting equipment. The position would have been very different if the policy had been to degrade standards to those of the "average" listener, even if it were possible to discover by statistical methods the type of equipment and listening environment employed by this hypothetical individual.

Colour Television in the United States

SIR HAROLD BISHOP'S VIEWS

THE director of technical services of the B.B.C., Sir Harold Bishop, spoke about colour television in the United States at a luncheon of the Radio Industries Club in London on April 24. Sir Harold had just returned from a visit to the United States.

He said that colour television had made a good start there but he thought progress would be slow until the price of sets dropped. The system which they had adopted—the N.T.S.C.—was capable of excellent results and intensive work on the development of television sets was continuing.

So far only about 25,000 colour television sets had been sold at a price of about 800 dollars (about £300) each. The service on these sets averaged about 100 dollars (£35) a year. The R.C.A. company was now making about 30,000 sets a month at a price of 700 dollars each. Sir Harold had been told that as manufacture developed it was hoped that the price would come down to about double the cost of an ordinary black-and-white television set.

Of the three big networks in the United States N.B.C. was radiating about 40 hours of colour television a month which was to be increased to 80 hours at the end of the year. C.B.S. was doing about 10 hours of colour television monthly and had recently reduced the hours. The other network—A.B.C.—was doing no colour transmissions.

Sir Harold Bishop referred to the cost of the programmes known as "spectaculars." They ran up to about a quarter of a million dollars (£90,000) for a half-hour programme.

About the prospects of colour television in Britain Sir Harold Bishop said that the B.B.C. had an open mind on what system should be adopted. It was the responsibility of the Television Advisory Committee—on which the Post Office, the industry and the B.B.C. were represented—to recommend the most suitable system. The B.B.C. had been accused in some quarters of spending public money in pushing a compatible colour television system on 405 lines. This was a misrepresentation of the facts. The B.B.C. was exploring all aspects of colour television for the information of the T.A.C., and its experiments would cover all bands and standards other than 405 lines in co-operation with the industry. It would be a long time before a decision was reached.

We regret that publication of *Wireless World* has again been delayed. Subsequent issues will appear at intervals of less than a month until the normal time of publication is resumed.

Reliability in Equipment

WHAT DOES IT DEPEND ON?

By ERNEST G. ROWE,* M.Sc., D.I.C., B.Sc.(Hons.), A.C.G.I., M.I.E.E.

EVERYONE in the electronics industry is vitally concerned with the need to achieve equipment reliability. No matter what specific field is involved, the demand is essentially the same—that the equipment marketed shall give the user trouble-free performance. Naturally the effort required to achieve this objective differs with the purpose of the equipment. At one end of the scale is the submarine repeater, where extreme precautions are taken because any failure will be inordinately expensive and at least 20 years' continuous operation is an economic requirement. At the other end of the scale is the sound and television broadcast receiver market, where it is nevertheless equally important to keep the set-owner satisfied.

In order to realize even a modest reliability in the overall equipment it must be appreciated that extremely high individual component reliability is necessary (see Fig. 1). During the last decade this problem has been very much in the forefront and has resulted in intense activity on the part of component makers and, in particular, the valve manufacturers, whose products have been demonstrated as giving more trouble than the others.

Hundreds of thousands of pounds have been spent in analysing the causes of valve failures, in establishing new valve designs which are free from such faults as were causing failures, and in the introduction of new manufacturing processes to produce valves in the higher category of reliability. While much of this work has been aimed primarily at producing valves to work under arduous vibrational conditions, it has been possible to utilize some of the knowledge so gained and to apply it to the mass of valves used in domestic sound and television. That the set designer knows this and has taken advantage of it is evident, because there are many cases where valves manufactured less than two years ago would no longer be acceptable in modern circuits.

The valve maker can now justly claim than when Special Quality valves are *used correctly*, the following problems may be regarded as solved: (1) Catastrophic failures which have been the cause of sudden equipment breakdowns. (2) Heater failures resulting from repeated switchings. (3) Microphonics and noise, particularly when associated with vibrational conditions. (4) Early life failures due to loss of emission and rise of "gas." It has also been established that the failure rates on such valves remain uniformly low up to some thousands of hours of operation.

What does all this mean in actual figures?

Well, the ordinary domestic valve for sound and vision sets has about 3% failures per year in the first year of operation. The same valves when used under vibrational conditions have shown average failure rates of the order of 20% in the first thousand hours of running.

However, the Special Quality valves designed to meet such arduous working give a corresponding figure of 1.5%.

To get better results than this is becoming increasingly difficult because the law of diminishing returns is beginning to operate and it is only by ignoring expense completely, and taking extreme precautions as well, that a figure better than 0.1% is possible.

What, then, is necessary if we are to get the higher orders of equipment reliability that are required for the future? As far as valves are concerned, if we take ideal equipment reliability as a figure of 100%, it is now apparent that even the perfect valve can only contribute 30% to that objective. The other 70% is the responsibility of the valve user, with 50% being dependent on successful equipment design, *operating the valve correctly and conservatively*, and 20% on the provision of satisfactory maintenance techniques.

Field Analyses.—There have been many large-

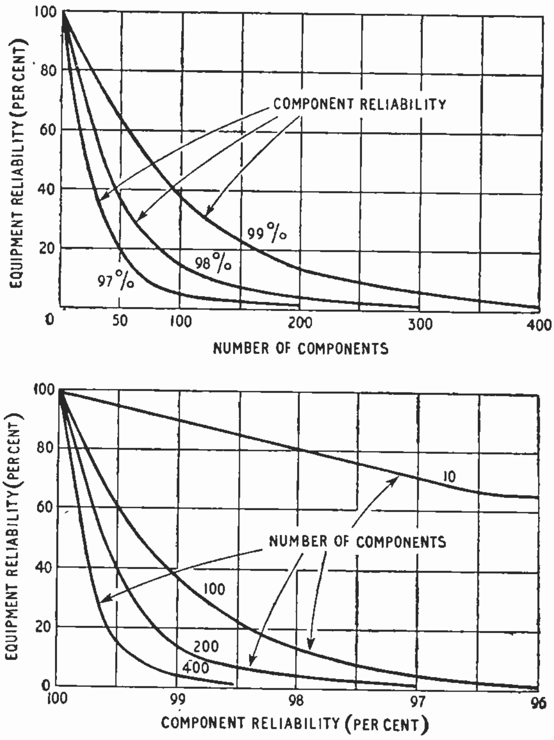


Fig. 1. Typical equipment-reliability/component-reliability relationships. With 100 components of average reliability 99%, the equipment reliability is only 40%, i.e. 2 out of 3 equipments would fail during a specified period. Increasing the components to 400 with the same average reliability means that 98 out of 100 equipments would fail in the same period.

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* Standard Telephones and Cables.

scale investigations under controlled conditions on large numbers of particular equipments but the following extracts are typical of the latest findings:

(i) In an equipment using ordinary domestic valves under arduous conditions the reasons for the failures of the valves in the various positions were as follows:

Position 1. Incompatibility between equipment design and valve specification.

Position 2. Excessive current surges in rectifier when switching-on due to the omission of the specified minimum series impedances.

Position 3. Faulty maintenance instructions.

Position 4. Critical for microphony and parasitic oscillations.

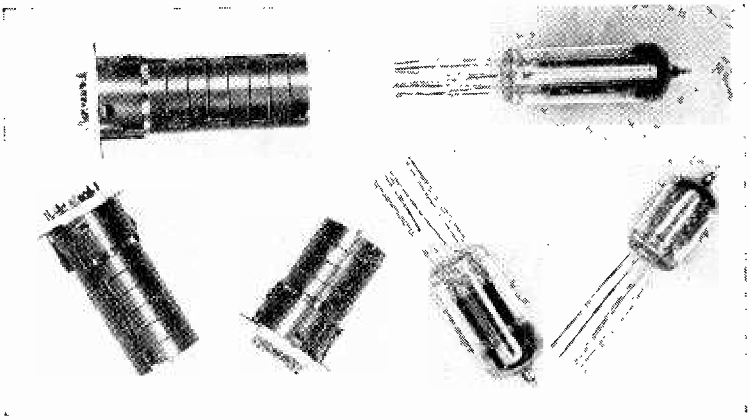


Fig. 2. Typical wired-in valves. Those to the right are normally placed horizontally on the chassis and held down with metal clamps. The left-hand three are supplied to the equipment manufacturer complete in sockets and with heat dissipating shields.

Position 5. Excessive anode dissipation.

Position 6. Heavy glass breakage due to removal difficulties in servicing.

Position 7. Bad valve design; mechanically weak.

Position 8. Use of wrong valve type, resulting in microphony.

Position 9. Excessive interelectrode leakage due to overrunning of the valve heater.

Position 10. Operation at too high a bulb temperature.

Position 11. Critical for noise and microphony.

(ii) In an equipment using Special Quality valves under arduous conditions, the reasons for the failures of the valves in the various positions were as follows:

Position 1. Operated above maximum ratings.

Position 2. Incompatibility of valve and circuit.

Position 3. Incompatibility of valve and circuit.

Position 4. High bulb temperatures causing bulb cracking.

Position 5. Weak performance; faulty circuit constants.

Position 6. Incompatibility of valve and circuit.

Such analyses as these demonstrate the many cases of trouble diagnosed as wrong valve usage, and that with Special Quality valves the whole onus of reliability will be thrown on the user. The valve is the most ubiquitous of all the components in an electronic equipment and it is subject to the most abuse. No equipment designer would think of using resistors or capacitors without allowing 100 or 200% safety factor on the published ratings but that same designer expects to be able to use valves at their published data or above without anticipating trouble because of this approach.

Design of Equipment.—Reliable electronic equipment design depends on: (a) the use of the most reliable components, of which valves are one; (b) the use of simple circuits wherever possible, with suitable derating of valves and components; (c) the use of new constructional techniques; (d) thorough testing under the conditions of use (this includes temperature and humidity cycling and vibration and shock testing); (e) the realization of the problems of the equipment user.

This brings to mind the concept of the "black box" or sub-unit with built-in methods of marginal checking and fault location. Methods such as these must be employed to supersede the arbitrary ones which start by the service technician removing the valves as his first action in fault diagnosis.

Such procedures must apply to all maintenance and servicing technicians. A typical example is in the ground servicing of aircraft. Valves have to be worked within a certain range of voltages and great care is taken on aircraft to ensure this. Yet it often happens that a ground service truck has manually operated or inadequately stabilized power supplies, as a result of which all the valves are subjected to excessive voltages.

It cannot be too strongly emphasized how important it is that valves should be used correctly. The valve is inherently a fuse and thus takes the blame for failures of equipment whether it is misused or has failed because of other component troubles or faulty servicing.

Because it is the valve that so often takes the blame, valvemakers' application laboratories have built up a concentration of knowledge gained by bitter experience. This information is freely available to all users of valves and, in addition, much of it has been gathered together in a document which explains the reasons for many of the desired precautions. This publication, known as the British Standards Institution Code of Practice CP1005 and entitled "The Use of Electronic Valves," should be in daily use by all circuit designers.

Similar documents have had restricted issue in the United States, but they all tell the same story, that careful attention to established rules, together with the closest collaboration with the valvemaker to ensure that he has adequately life-tested valves for use under specified conditions and has incorporated such conditions into his manufacturing test specifications, will result in greatly improved equipment reliability. There is increasing evidence that the Americans are taking more positive action than we are to ensure compatibility of components in equipment. They have elaborate and efficient field surveillance of failures whereby equipment and valve faults are classified. If valve manufacturers find equipment rejections of valves passing their specifications, they can ask for an independent investigation of the equipment to the mutual benefit of both customer and supplier, and there are plans for the widespread dissemination of the experience gained by the issuing of suitable handbooks. They have gone so far as to have task teams of applications engineers who co-operate with the government services on any required project.

In this country many firms in the electronics industry are introducing "reliability groups" whose function is to supply reliability information to designers and manufacturers. Such groups conduct studies on current designs so that the mistakes of the past are not repeated in future designs, and in many cases are responsible for investigating new concepts, new designs, changes in manufacturing techniques and advanced technology.

As so much of the work carried out is now being published it should be easy for future university courses for graduate engineers to include lectures on the reliability concept, and for lecturers to explain statistical and probability theories as essential tools for the electronics engineer to use in parallel with his basic theory.

If these approaches are effective, and they must be if the electronics industry is to achieve reliability, what are the future plans of the valve-makers? From the production point of view it is possible for the techniques of "automation" to be exploited, not only to meet competition, reduce costs and overcome shortages of skilled labour, but also to contribute to the achievement of higher orders of reliability. Such techniques when applied to valves require more standardization and reduction of types, and, in some cases, new concepts in design from the outset.

The valve research engineer has realized that, having eliminated catastrophic failures, the major cause of valve failures is now the simple deterioration of valve characteristics. Five years ago, civil aviation would have been content with 1,000 hours reliable operation, but now it is usual for operating companies to fly 4,000 hours a year and so trouble-free performance is required for many thousands of hours.

As a result a great deal of research is being done in basic design, newer and better materials, new processing techniques and machinery to produce valves having consistent lives of the order of 20,000 hours or more. This work will take time, but the prospects are very good that valves, when used properly, can be fitted and forgotten.

Co-operation between valve-makers and equipment designers has already produced many exciting new approaches—unit system of construction, printed and potted circuits, mechanical jointing and other methods of avoiding dry joints.

It is not too early, either, for valves to become wired-in components (see Fig. 2). Already it has been established that the mechanical incompatibility between the pinned valve and the valveholder causes a considerable and continuing failure percentage. Also, that with the latest Special Quality valves there are more chances of equipment failures being caused by other components, so there can be no real objection to a system which precludes valve replacement as a maintenance practice.

Equipments are already in use employing wired-in subminiature, miniature and noval types, and in the future the transistor will also take its rightful place, filling a need that in many cases cannot be met by the thermionic valve.

High-density Polythene

A NEW grade of polythene to be known as "Alkathene H.D." has been put into production by the I.C.I. high-pressure process. Its electrical properties are the same as those of standard "Alkathene 20," but it has greater mechanical stiffness and tensile strength, and the softening point has been raised from 83°C to 116°C. At low temperatures the brittle point is below −70°C, compared with −30°C for standard "Alkathene."

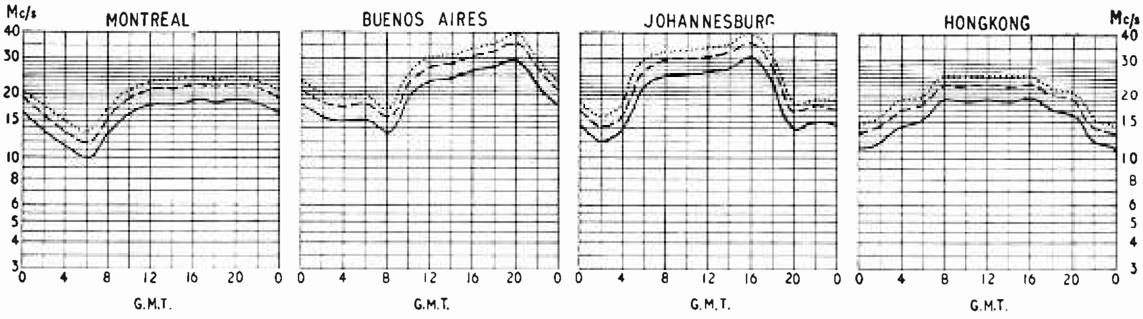
The higher density (0.94 compared with 0.92 gm/cc) is accompanied by lower permeability to gases and vapours and by greater resistance to oils and fats.

For electrical applications one of the principal advantages is the possibility of thinner and tougher coverings for wires and cables, and higher working temperatures.

Limited supplies will be available this year for trial at 4s per lb, irrespective of quantity.

SHORT-WAVE CONDITIONS

Predictions for May



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 May.

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

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

— — — PREDICTED AVERAGE MAXIMUM USABLE FREQUENCY

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

Heads, Tails and Noise

By "CATHODE RAY"

Simple Probability Theory in the Movements of Free Electrons

LONG, long ago, in the very early days of broadcasting, I remember being quite amused because someone proposed to fit what he called a volume control to a receiver. Readers who are not well versed in ancient history will need to have this joke explained to them. It is just that in those days there was never any spare volume to control. The programme could only be heard at all by making everyone keep quiet and carefully adjusting the "reaction" knob to the very brink of oscillation. Any reduction in volume that even the hopeful enthusiast seemed likely to need was obtainable by slightly reversing the adjustment.

Since then, amplification has been so much developed—and the power of transmitters so much increased—that the problem is less to bring the wanted programme in than to keep everything else out. A very familiar part of that problem is the keeping of other programmes out. Another part of it is that although, technically, there is hardly any limit to the amount of amplification that can be provided, a limit is very soon reached to the amount that can usefully be employed. That limit is imposed by noise.

To the general public, noise is something one hears. It would, therefore, surprise them to see it defined (in B.S. 204:1943) as "unwanted energy." The full definition is

> Unwanted energy (or the voltage produced), usually of random character, present in a transmission system, due to any causes.

This says nothing about sound or hearing, or even loudspeakers. And why "transmission system?" To explain that last point first, it should be understood that it covers the whole of any system of electrical communication, and not only what is usually called the transmitter—more accurately, the sender. If the system happens to be a telephone or sound broadcasting, the end-product of the unwanted energy is what the non-technical person understands by "noise." The communications engineer uses that word to denote the cause of the sound—the unwanted energy, in fact—rather than the sound itself. But unwanted energy, even if of a random character and present in a transmission system, does not necessarily cause a sound. Its effects can be shut off by disconnecting the loudspeaker, or may emerge in quite a different form on the screen of a television tube, without making any difference to the unwanted energy. So to the radio engineer there is nothing incongruous in referring to a grainy TV picture as "noisy." And, of course, radar operators are familiar with the silent noise that drowns weak echoes (also silent!).

One class of technical noise is termed "man-made" (in which "man" embraces "woman"). Another is caused by thunderstorms and other large-scale natural phenomena. But even if man were to cease from troubling and the weather were at rest there would still be an irreducible barrier of noise, caused by small-scale natural phenomena, known as fluctuation noise, thermal-agitation noise, Johnson noise, shot effect, and Schottky noise. These are not all different. "Fluctuation noise" covers two main kinds, the first being due to the ceaseless jostling of electrons in resistors and known alternatively as thermal-agitation or Johnson noise, and the second is due to the electronic nature of current in valves and is called shot effect or Schottky noise. I have already written about them at some length, but as that was years ago* and the present development of f.m. broadcasting is directing attention to the suppression of noise it may not be out of place to look at the nature of fluctuation noise again.

One can deduce quite a lot about thermal noise in resistors from basic principles. Readers who have not gone into this before may be surprised and perhaps rather mystified to learn that the basic principles particularly concerned are the first and second laws of thermodynamics. The first law is that there is a fixed rate of exchange between heat energy and mechanical energy. When a substance receives heat its store of mechanical energy is thereby increased. If the substance started to fly about the room one could easily believe it. Sometimes it actually does just that—if the temperature rises sufficiently to make the substance boil. If it remains solid there seems to be no evidence of mechanical energy. But its very solidity is an illusion. A cumulus cloud looks solid and clear-cut and rigid at a distance, but on close acquaintance turns out to be mere swirling mist. And if we could get an atom's eye view of a solid wire it, too, would be seen to have plenty of room for mechanical movement within itself. Electrons would be ricocheting about in all directions, and what happened to the incoming heat energy would at once become clear. It is stored as energy of movement (kinetic energy) throughout the substance. The higher the temperature the more energetic the movement.

We can see that the substance as a whole is not moving, so the movements of its particles must be like the movements of people forming a crowd which as a whole remains stationary—they must be random, those in any one direction being more or less cancelled out by movements of other particles in the oposite direction.

So far as we are concerned, the most important part of this description is the phrase "more or less." For any movement of electrons is an electric current.

**Wireless World*, May and June, 1952.

So long as exactly equal numbers of electrons are moving in opposite directions the currents cancel out so that none can be detected externally. That could hardly happen all the time unless it were organized. But the only system about their movement is the complete absence of system; their movements are perfectly random. There is nothing whatever to ensure that they would never happen to be all moving in the same direction at the same time, causing a colossal electric current. The future of such an entirely uncontrolled regime might seem to be quite hopeless to predict, yet in fact it can be foretold with incomparably greater confidence than things which are supposed to be under control, such as the economic state of the country. (Is it possible that the anarchists have got something, after all!)

No Exact Balance

This is such an interesting point that it will be worth coming back to, but in the meantime let us just assume that because the heat-generated or thermal movements of electrons in a substance are random there is seldom an *exact* balance between those moving one way at any moment and those moving the opposite way. Mostly there is a slight excess one way or the other, fluctuating all the time. Any net movement of electrons between the two terminals of a resistor is an electric current, and it sets up a difference of potential between those terminals. Fortunately, these currents and voltages are small, but if extensively amplified they are sufficient to be heard in a loudspeaker, which, of course, is how they came to be termed " noise." The type of sound is usually likened to an escape of steam.

The chief thing we want to know about it is how to stop it, or at least reduce it to a minimum. Because the first law of thermodynamics tells us that the noise energy is directly proportional to the heat, an obvious suggestion is to remove all the heat from the parts of circuits that are followed by sufficient amplification to make the noise a nuisance. This necessitates reducing their temperature to −273°C, so it is an entirely unpractical idea. Even if we were to take the trouble to keep the equipment in the " fridge " and thereby risk domestic strife, the reduction would be only about one tenth or less, so hardly worth it. The noise power is, in fact, proportional to the absolute temperature (°K) which is the number of centigrade degrees above −273.

How does it depend on the resistance of the circuit? We can get a clue from the second law of thermodynamics, which says that heat can't go from one body to a warmer one without, as it were, some " heat-motive force." So if we connect two resistors at equal temperature in parallel, as in Fig. 1, each must deliver to the other noise energy at the same rate, whatever their resistances. For if the energies didn't balance there would be a transfer from one to the other and one resistor would become warmer and the other cooler. Even without any laws of thermodynamics we could guess that this couldn't happen, for any single resistor can be considered as two in parallel, by splitting it endwise, and if we consider in turn different cleavages the idea can easily be reduced to an absurdity.

But let us take two separate resistors, R_1 and R_2 in Fig. 1(a), connected in parallel, then calculate the noise power each delivers to the other, and make use of our knowledge that these powers must be equal. To make current flow in this circuit it is necessary to have an e.m.f. Each of the innumerable flying electrons can be regarded as a miniature e.m.f., but to save time we shall lump all those in R_1 together as a fluctuating e.m.f. E_1, driving a noise current I_1 into R_2; and similarly for R_2, as in Fig. 1(b). By the principle of superposition, these currents can be considered separately.

The power developed in a resistance R by a difference of potential V across its terminals is V^2/R. The p.d. across R_2 due to E_1 is, of course, $E_1R_2/(R_1+R_2)$, so the power in R_2 is $E_1{}^2R_2{}^2/(R_1+R_2)^2R_2$, or $E_1{}^2R_2/(R_1+R_2)^2$. Doing the same for R_1 and equating the powers:

$$\frac{E_1{}^2R_2}{(R_1+R_2)^2} = \frac{E_2{}^2R_1}{(R_1+R_2)^2}$$

So $$E_1{}^2R_2 = E_2{}^2R_1$$

and $$\frac{E_1{}^2}{R_1} = \frac{E_2{}^2}{R_2}$$

In words, the square of the equivalent noise e.m.f. divided by the resistance is the same for resistors 1 and 2. But this principle would obviously apply to any resistors, so we can say that noise e.m.f. squared, divided by resistance, is a constant. Remember, however, that we have been assuming that the resistors are at the same temperature. There is also a complication arising from the fact that thermal noise power, being completely random, occurs equally at all frequencies, and in practice one can only measure it over a limited band of frequencies at a time. For one thing, noise at the very highest frequencies would always be reduced by stray capacitance across the resistance. So a second condition for E^2/R being constant is that E must be reckoned across the same band of frequency. This qualified constant, to which E^2/R is equal, is in fact

$$4kTB$$

where T is the absolute temperature, B is the bandwidth in c/s, and k is a real constant, called Boltzmann's, of value 1.38×10^{-23}. Put another way, the noise voltage $E=\sqrt{4kTBR}$.

If you preferred, instead of the equivalent voltage generators in series as in Fig. 1(b) you could have used the equivalent current generators in parallel with R_1 and R_2, delivering noise currents to R_1 and R_2 inversely proportional to their resistances. This works out, in a somewhat similar manner, to $I_1{}^2R_1=I_2{}^2R_2$, showing that in general I^2R is constant, or the noise current is proportional to $1/\sqrt{R}$. The same conclusion is reached from the previous re-

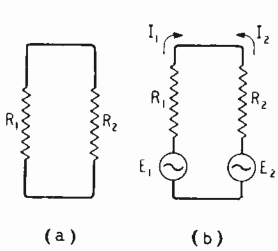


Fig. 1. Any resistor is a noise generator, so if two are connected in parallel (a) each will deliver noise power to the other. Working from the principle that the exchange of power must be equal, one can easily show that each noise e.m.f. in the equivalent circuit (b) must be proportional to the square root of its own resistance.

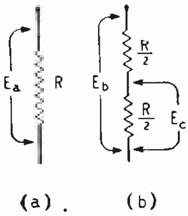


Fig. 2.

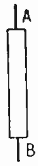


Fig. 3.

Fig. 2. From the result of Fig. I it is clear that adding together two equal noise voltages gives a total that is not twice that of either but $\sqrt{2}$ times.

Fig. 3. The noise problem in a resistor is simplified by assuming that the movements of electrons inside it are all from A to B or from B to A.

sult simply by substituting IR for E, in accordance with Ohm's law.

It is a very well-known fact that the power delivered by a generator to a load is greatest when the load resistance is equal to the generator resistance. The generator e.m.f. (say E) is then equally divided between generator and load, so that the terminal voltage is E/2. The maximum power into load resistance R is therefore $(E/2)^2/R$. Applying this to our noise-voltage $E = \sqrt{4kTBR}$ we get as maximum power kTB. The interesting thing about this is that it doesn't depend at all on the size of the resistor responsible for the noise, or how many electrons it has inside to generate the noise. But remember that the maximum noise *voltage* is obtained when the resistor is open-circuited, and is then equal to E, which is not the same for all resistors but is proportional to the square-root of their resistance.

Another interesting thing can be gathered from Fig. 2. It is obvious that E_b must be equal to E_a, because two resistances R/2 in series are identically the same as R. It might also be supposed than E_b was twice E_c, seeing that two voltages in series, each equal to E_c, add up to E_b. But whereas $E_a = \sqrt{4kTBR} = E_b$, $E_c = \sqrt{4kTBR/2}$, so

$$E_c = \frac{E_b}{\sqrt{2}} = 0.707E_b$$

not half E_b. The reason, of course, is that the noise voltages developed by different portions of a resistor are entirely unrelated; sometimes they may happen to add up directly, sometimes they may cancel one another completely out, and most of the time they are somewhat between. As we saw some time ago,* when two alternating voltages in series are liable to have all possible phase relationships, their *squares* add up. In Fig. 2(b), then

$$E_b^2 = E_c^2 + E_c^2$$

or

$$E_b = \sqrt{2}\,E_c$$

which is the same as we found as a consequence of the relationship between resistance and noise voltage, which in turn followed from the second law of thermodynamics. As power is proportional to voltage-squared, it is true to say that noise *powers* add up directly.

And now we can get back to the question that may have been puzzling some people: how is it that currents and voltages that arise purely from chance can be so definite that their values can be calculated from the simple formulæ we have seen? A full answer would fill a book†; but we might have just about enough space left here to get a rough idea.

An ordinary piece of conducting material, such as a resistor is made of, consists of a stationary pattern of atoms, with vast numbers of electrons flying about in the spaces between. Although most of the material is empty space, the electrons are moving so fast at earthly temperatures that they are continually colliding with the atoms and being deflected into some other direction. The whole thing being more chancy even than a roulette wheel, all directions are equally likely, and one can base calculations on that assumption.

What we are interested in is the net movement of electrons towards or away from either terminal, because that is what causes the trouble. In Fig. 3 the terminals of a resistor are marked A and B. Electrons moving horizontally have no effect and those moving vertically have maximum effect, while intermediate directions are intermediately effective according to the angle. This complication can be taken care of in the mathematics, but to simplify the picture let us imagine that all electrons are moving vertically, either up or down.

Suppose at first that there was only one electron, and somebody was making a note of its direction at regular intervals of time. This situation would be similar to someone repeatedly tossing a coin at random and noting the result of each throw. At any one throw a head or a tail would be equally likely. That does not mean that in any even number of throws heads and tails would always come in equal numbers. In any two throws there are four equally likely possibilities; (1) HH, (2) HT, (3) TH, (4) TT. So two of the same are just as likely as one of each. In three throws there are eight equally probable results, because each of the foregoing four gives rise to two alternatives, depending on whether the third throw yields a head or a tail. Out of these eight, only one is all heads and only one all tails. This process can be continued indefinitely, and mathematical methods have been devised to enumerate the probabilities beyond the point at which it becomes too tedious to write down all the possible results of a sequence of throws. The greater the number of throws, the smaller the proportion that are likely to be all of one kind and the greater the tendency to average out at equal numbers of each.

Odds and Probabilities

This does not mean that an *exactly* half-and-half result ever becomes highly probable, because the greater the number of throws the greater the number of alternative possibilities. Although the most probable result of a million throws is exactly half a million of each (so that one would be justified in calling this the " normal " result) the odds are in fact 1,770 to 1 against it. Deviations from normal of up to about 100 each way are almost equally probable. Much beyond that, the probabilities fall off very steeply—see Fig. 4—and soon become fantastically small. The chance of getting 502,000 heads in a million is 97,000 to 1 against, and 505,000 heads is 130,000,000,000,000 to 1 against! So although theoretically there is a possibility that a million consecutive throws might yield a million heads,‡ with large numbers one can entirely ignore

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*" Total Power," *Wireless World*, March 1952.

†A good one to study is " Frequency Analysis, Modulation and Noise," by S. Goldman (1948, McGraw-Hill Book Co.).

‡Merely to write down the number representing the odds to 1 against, at the rate of two figures per second, would take 60 solid hours! To describe such a number as astronomical would be a superlative understatement.

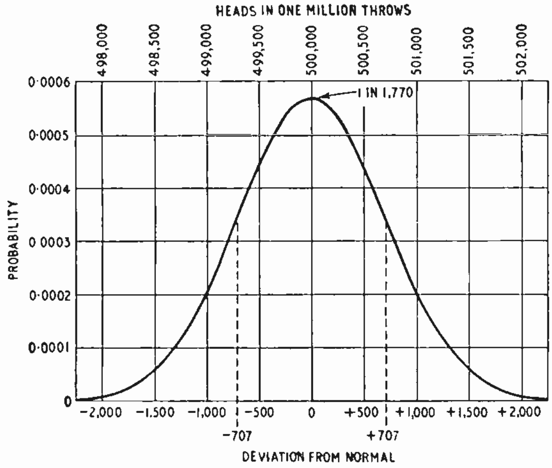

Fig. 4. This graph shows the probability of obtaining a given number of heads in a million random tosses of a coin. For numbers differing more than about ¼% from half a million the probabilities are too small to show. The same graph applies to tails—and to the number out of a million electrons moving in one of two equally probable directions. ± 707 is the r.m.s. value of the deviations from normal, taken over a period of time.

the possibility of any but very small deviations from normal.

Still, these small deviations are important, because they are the basis of our noise. The pattern of probabilities for a million tosses of a coin applies equally to a million electrons moving up or down. At any given moment, the odds are 1,770 to 1 against exactly equal numbers moving in each direction. Nearly all the time there is an excess one way or the other; this fluctuating excess is noise. The odds are even more heavily against the excess ever being more than a very small proportion of the total number of electrons involved. So if at any time you decide to make a spot check of instantaneous noise current you are almost certain to find it between quite narrow definable limits. Fig. 4 shows that in a gathering of a million electrons the noise current is less than 2,000 electrons (one-fifth of one per cent) nearly all the time. In any significant part of a circuit there are vastly more than one million electrons, and the greater the number the smaller the percentage excess likely to occur one way or the other.

It must be remembered that the Fig. 4 pattern (called, incidentally, a Gaussian or normal error distribution) shows the most probable values of *instantaneous* noise current. From the fact that they are symmetrical about zero, we can gather that over a period of time the positive and negative values will average out, which means that noise has no long-term d.c. component.

Fig. 4 also shows that the *peak* noise current, even over quite a long period, is unlikely to exceed say one per cent of the theoretically possible one million electrons. The smaller percentages of larger numbers of electrons can easily be calculated from the Gauss formula used for plotting Fig. 4.*

But what would be even more helpful is the r.m.s. value, because that is the value which, when squared, represents noise power, and, as we have seen, separate noise powers can be added directly to give total noise power. Calculating the r.m.s. value from mere probabilities might seem to be a rather difficult and not altogether reliable enterprise. But although the r.m.s. value of the fluctuations itself fluctuates appreciably if it is reckoned over a short period, over a long period (such as a second or two!) it remains steady enough to be given a definite figure. And this figure agrees well with measurements. By means of mathematical manipulation that can be found in the appropriate books, such as the one I mentioned, it can be shown that it is equal to the square root of the average number of electrons going one way (i.e., half the total electrons). So for Fig. 4 it would be 707.

The r.m.s. number of excess electrons is, of course, not by itself a value of current. To determine the current one has to know how fast the electrons are moving so as to calculate how many are passing a given point per second.* That is where the temperature comes in; the higher the temperature, the faster the electrons move. It is also where the resistance comes in. Just how it comes in does not immediately spring to the mind, unless your mind works a good deal faster than mine. But it can be arrived at in stages, like this:

Let D denote the r.m.s. value of the electron fluctuation. If we have looked up the right book we will have seen that by purely mathematical processes D is equal to $\sqrt{n/2}$, where n is the total number of electrons in circulation. Now the conductivity of a material is proportional to the number of circulating electrons per unit of volume. Assuming the length of the piece of circuit in question is l and that it has a uniform cross sectional area A, its volume is lA, so its conductivity is proportional to $n/l\mathrm{A}$. Its resistivity ρ is just the conductivity upside down, so

$$\rho \propto \frac{l\mathrm{A}}{n} \qquad \therefore \quad n \propto \frac{l\mathrm{A}}{\rho}$$

And therefore, substituting $\mathrm{D} = \sqrt{n,/2}$ we have

$$\mathrm{D} \propto \sqrt{\frac{l\mathrm{A}}{2\rho}} \propto \sqrt{\frac{l\mathrm{A}}{\rho}}$$

But the resistance $\mathrm{R} = \frac{l\rho}{\mathrm{A}}$, so $\rho = \frac{\mathrm{AR}}{l}$

$$\therefore \ \mathrm{D} \propto \sqrt{\frac{l\mathrm{A}l}{\mathrm{AR}}} = \frac{l}{\sqrt{\mathrm{R}}}$$

The number of fluctuating electrons per unit length of circuit is of course D/l, and if they are moving at the rate of v units per second the number to pass a given point per second (to which the r.m.s. noise current I is proportional) is $\mathrm{D}v/l$. And v is proportional to the absolute temperature T, so

$$\mathrm{I} \propto \frac{\mathrm{D}v}{l} \propto \frac{\mathrm{DT}}{l}$$

Lastly, substitute $\mathrm{D} \propto l/\sqrt{\mathrm{R}}$ from above, and

$$\mathrm{I} \propto \frac{l}{\sqrt{\mathrm{R}}} \cdot \frac{\mathrm{T}}{l} = \frac{\mathrm{T}}{\sqrt{\mathrm{R}}}$$

So the upshot of all this is that the r.m.s. noise current is proportional to the absolute temperature and inversely proportional to the square root of the resistance. And wasn't I relieved to find it worked out in agreement with the previous results!

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*The probability of a deviation d from the average $n/2$ in a number n is $\frac{\exp. -d^2/n}{\sqrt{\pi n}}$

*6,242,000,000,000 of them per second make one microamp.

More Lines *Instead of* Colour?

Higher Definition Should Come First

By D. A. BELL, M.A., Ph.D.

THE defence of the 405-line system by V. J. Cooper (*Wireless World*, April, 1956, p. 173) rests on three main arguments:

(*a*) Bandwidth is limited, and the "value" of television does not justify the use of any greater bandwidth than at present.

(*b*) For a given number of lines, it is useful to employ a greater bandwidth than is calculated on the traditional basis of a half-cycle per picture point.

(*c*) "Economic factors must surely be predominant in deciding standards."

As regards (*b*), the present writer has argued[1] that on theoretical grounds, for the perfect reproduction of all signal waveforms, the traditional minimum bandwidth should be doubled, not merely increased by 50%. But this still does not tell us the subjective difference between two systems which differ both in number of lines and in relative bandwidth. In reply to (*a*), some might say that the programmes offered are so valueless that no bandwidth at all should be devoted to television broadcasting: anyone eccentric enough to want this kind of thing should pay for a wire relay system. Alternatively, one can say that some of the programmes are very good, and deserve to be presented more adequately than is possible with 405 lines; and in consequence the use of 3 Mc/s to transmit these programmes inadequately, instead of 10 Mc/s to do them justice, is in fact a waste of the 3 Mc/s.

But the crux of the matter is the viewer's judgment of the picture on the home receiver. During a recent visit to France, the writer went into the lounge of an hotel in Grenoble to glance at the television and was astonished at the detail and the absence of visible lines. One knew that at the end of the war an 819-line system was developed in France, in addition to the earlier 441-line system, but the writer had overlooked the fact that the whole of French television is now on 819 lines and not on the "European" standard of 625 lines. This choice by the French authorities is justified by the fact that one glance at the received picture brought conviction that the system producing it could be nothing less than the 819-line system. Its standards are as follows: 819 lines, with interlace; 25 complete pictures per second; fly-back time, 10%; video passband, 10.5 Mc/s; separation between vision and sound carriers, 11.15 Mc/s; nominal channel width (including guard bands), 14 Mc/s; carrier-frequency range, 164 to 200 Mc/s.

At the beginning of 1956 there were 10 transmitters operating, as listed in descending order of e.r.p. in the table, and it is planned to increase this number to 37 by the end of 1958. The powers used are affected by geographical conditions as well as by the area of population to be covered, and the programmes seen in Grenoble had been relayed from the local 300-watt transmitter which is on a 7,500-ft mountain situated 15 km from the centre of the town. It was true to say that interference was negligible, and in particular car ignition interference was not seen, though on occasion a very fine moire pattern could be detected by looking closely.

The great advantage of the higher definition is that large-scale effects can be presented with adequate detail, e.g., a display of massed folk-dancing—and solo artists are normally presented as three-quarter-length or full-length portraits, not head-and-shoulders only. It liberates television from the state of being a specialized art having limited effects at its disposal in order to *represent* some form of entertainment, and makes it as free as the black-and-white film to *reproduce* visual entertainments where so desired, or use more natural "shots" if the moving picture is regarded as an artistic work. The standard sizes of picture tube in France are 17in and 21in, which is comparable with the size of picture presented by the 16-mm cinema in the home, and in spite of all arguments about optimum angle of vision seems pleasing. On the other hand, the camera craft in some of the programmes seen by the writer was poor by British standards. Camera shading effects were common, and on one occasion a switch to a second camera turned the picture temporarily into a soot-and-whitewash display that was almost unrecognizable. A difficulty associated with high definition is that when an announcer, for example, is shown seated in the centre of the picture, there is a large expanse of plain background in the picture. On some occasions flicker was just perceptible on this high-light area. It is just possible that this may have been due to external interference, but it could be due to the fact that the sensitivity of the eye to flicker increases with brightness level: it has been claimed[2] that a European television image on 50 c/s must not exceed one-sixth of the brightness which could be used on an American 60 c/s image for freedom from flicker. This is merely another point to watch in studio

TABLE I

Transmitter	E.R.P. (Vision)
Lille	200 kW
Paris	100 kW
Marseille	50 kW
Strasbourg	20 kW
Grenoble..	300 W
Reims	300 W
Lyons	100 W
Metz	100 W
Nancy	100 W
Dijon	50 W

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[1] D. A. Bell. Economy of Bandwidth in Television, *J. Brit. I.R.E.*, **13** (1953) 447.

[2] C. J. Hirsch. Television in the World Today, *Electrical Engg.*, **75** (1956) 321.

technique, avoiding large high-light areas when the field of view is enlarged.

The French television service is entirely government operated, and the licence fee is 4,500 francs. At the official exchange rate this is about £4 10s, but in terms of food prices and wages it might well be argued that 4,500 francs does not, in practice, mean more than our fee of £3. The number of receivers has been increasing exponentially, is now about 300,000, and is expected to saturate at about 4½ million: this would represent one television receiver for every three homes. Programmes are a matter of personal taste, but on a small sample they seemed a fair mixture of travel film, news, political interview and variety show, with perhaps more political interview and comment than we have.

What is the moral of this for the British viewer? In 1945 there were arguments for retaining 405 lines and arguments for a system around 600 lines, but the French results have made it clear that we ought to be planning now for 819 lines. Unfortunately the present plans for I.T.V. and for B.B.C. alternative programmes have allocated Bands II and III, and if we install a 405-line service in both these bands we shall have made it virtually impossible for Britain to have a high-definition television service within the foreseeable future. Instead, there is talk of introducing colour because there is a method of making that "compatible." In the past, in such controversies as f.m. versus a.m. sound and high- versus low-definition television, it has always been argued that it is important to avoid anything which would greatly increase the cost of a receiver. This was Cooper's final argument in defence of 405 lines. But can it be said that the introduction of colour satisfies this criterion? It can rather be suggested that whereas increasing the i.f. bandwidth and the timebase speeds is a routine operation, the design of a compatible colour receiver involves such fun and games for the research engineer that he regards the result as a notable contribution to technical progress—and, broadly speaking, the cost to the purchaser will be in proportion to the amount of technical ingenuity which the designer has to exercise. The following table (based on data published in *La Télévision Pratique*, Jan., 1956) gives an idea of the effect of the greater bandwidth on the design of commercial television receivers: in comparing with British practice, it must be remembered that these are all operating in Band III.

TABLE 2

R.F. Stage:—	Cascode	Single pentode	Unspecified
No. of models	57	5	3

No. of I.F. Stages ..	2	3	4	5	6
No. of models ..	6	24	25	7	3

The majority of these receivers claim a bandwidth of 9 to 10 Mc/s, and the few with only two i.f. stages are described specifically as local-station receivers. A noticeable design feature is that the difference between medium- and long-range receivers (the latter being for 50-75 miles range) is in the elaboration of the synchronizing circuits rather than in the amount of gain provided.

The specifications of these French receivers confirm that there is no serious economic problem in the design of a wide-band television receiver, and if colour television in any form can be contemplated the economic argument has been so thoroughly abandoned that it is a red herring to drag it up in connection with standards of definition. It seems to be agreed that the proposed system of compatible colour could be applied equally to transmissions on higher definition than the present British and American standards, and the question is whether the introduction of colour is more urgent than the raising of definition. Having seen high-definition transmission, under typical user conditions in which a standard commercial receiver was operated by persons with no technical knowledge, the writer has no hesitation in saying that high definition should come before colour. When you go to the cinema, do you look to see whether the film is in colour before you decide to go to a particular film? Do you even remember how much of the last film programme you saw was in colour? Unless your answers to these questions are very different from the writer's, you ought to be asking whether it is right to pursue the expensive luxury of colour while accepting in perpetuity the limitations imposed by 405 lines.

CLUB NEWS

Barnsley.—"Crystal-controlled convertors" is the subject of the talk to be given by H. Eyre (G5KM) to the Barnsley and District Amateur Radio Club at 7.0 on June 8th at the King George Hotel, Peel Street. Sec.: P. Carbutt (G2AFV), 33 Woodstock Road, Barnsley.

Birmingham.—The June meetings of the Slade Radio Society will be held on the 8th and 22nd. At the first meeting D. W. Morris will deal with industrial electronics and at the second a member of the staff of Mullards will speak on "Oscilloscope design and applications for amateur use." Both meetings will be held at 7.45 at The Church House, High Street, Erdington. Sec.: C. N. Smart, 110 Woolmore Road, Erdington, Birmingham 23.

Bromley.—On June 1st, George Hicks (G4JP) will speak at the meeting of the Bromley Radio Club on "R.C.A. high-fidelity sound amplification." Meetings are held at 8.0 at the Shortlands Hotel, Station Road, Shortlands, Kent.

Chelmsford.—At the June 14th meeting of the Chelmsford group of the British Amateur Television Club, F. Turner will speak on 70-cm transmitters. The meeting will be held at 7.30 at 10 Baddow Place Avenue, Great Baddow. Sec.: D. W. Wheele (G3AKJ), 56 Burlington Gardens, Chadwell Heath, Essex.

Newcastle.—The next meeting of the North East Amateur Transmitting Society will be held on June 5th at 7.45 at the Liberal Club, Pilgrim Street. Sec.: O. W. Docherty, 130 Grainger Market, Newcastle-upon-Tyne 1.

Servicing Exams : Record Entry

A TOTAL entry of 822 candidates for this year's examination for the Radio Servicing Certificate, for which the practical test was held on May 12th at 41 centres, is announced by the Radio Trades Examination Board. This is an increase of approximately 60% on the 1955 figure—the previous record.

A condition of entry for the examination for the Television Servicing Certificate is that the entrant must hold the Radio Servicing Certificate and the number of entries is therefore considerably smaller. The total of 137 is, however, an increase on previous years. The practical test is on June 16th.

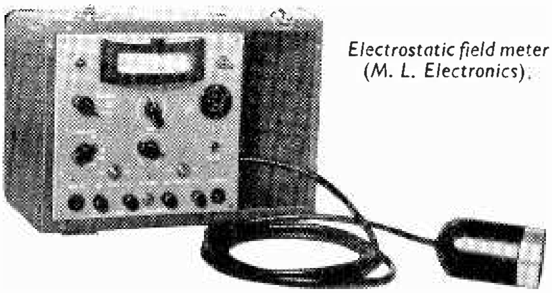
Both these servicing certificate examinations are conducted jointly by the City and Guilds of London Institute and the R.T.E.B. (9 Bedford Square, London, W.C.1) from whom particulars of future examinations are obtainable.

Manufacturers' Products

NEW EQUIPMENT AND ACCESSORIES FOR RADIO AND ELECTRONICS

Electrostatic Field Meter

FIRE and explosion hazards associated with the fortuitous generation of high electric field strengths in many manufacturing processes are reduced if early warning of the growth of the field can be given. In the meter made by M. L. Electronics, Ltd., Holly Road, Twickenham, Middlesex, separate output terminals are provided from which a signal is applied to any form of alarm relay when the field strength exceeds a predetermined level.



Electrostatic field meter (M. L. Electronics).

The potential developed on a probe electrode is modulated by alternately exposing and shielding the electrode by an earthed rotating shutter. After amplification the signal is applied to a phase-sensitive detector and measured by a centre-zero instrument which indicates the polarity of the field. The full-scale reading can be varied between 1 and 9 kV/metre and an outlet plug provides 300 volts for calibration purposes. Terminals are also arranged for connection to a recorder.

Television Turret Tuner

A TOTAL of 12 channels is provided in a new television turret tuner recently introduced by Brayhead (Ascot), Ltd., Full View Works, Kennel Ride, Ascot, Berks. The tuner has two valves, a twin-triode neutralized cascode r.f. stage and a pentode-triode mixer/oscillator. The input impedance is 75 ohms.

The aerial coil segments on the turret provide for use of bandpass circuits as these may be required with a high i.f. (35-38 Mc/s) on Band I to ensure trouble-free operation on Channel I, or to give good image signal rejection on Band III with a low i.f. Bandpass circuits are used also between the i.f. and mixer stages.

Oscillator injection is by a combination of inductive and capacitive couplings, while drift is compensated for by means of negative-temperature coefficient capacitors. On Band I these limit the drift to −85 kc/s and on Band III to +35 kc/s to −88 kc/s. Fine tuning of the oscillator (concentric with the turret-operating spindle) allows for a variation of 700 kc/s on Band I and 3 Mc/s on Band III. Coils are mounted radially and cores adjusted through holes in the turret.

Although produced primarily for set manufacturers the tuner is available to home constructors.

Moving-coil Loudspeakers

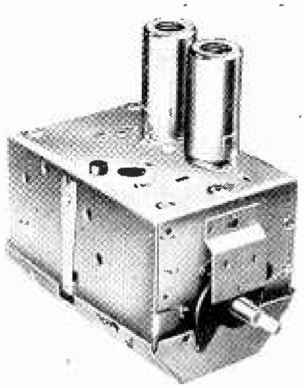
THE Lorenz (German) moving-coil loudspeaker system is now available in this country through Technical Supplies, Ltd., 63, Goldhawk Road, London, W.12. Known as Type LP312-2 it comprises a 12-in low-frequency unit and two 2½-in high-frequency units mounted with divergent axes on a bridge across a diameter of the larger unit. The flux density is 17,500 gauss in each case; but the impedance of each h.f. unit is 5.5 ohms and of the l.f. unit 15 ohms. Component values and a circuit for a suitable cross-over network (2000 c/s) are supplied; also the dimensions of suitable alternative vented cabinets. The nominal overall frequency coverage is 15 c/s to 22.5 kc/s with a power rating (average) of 25 watts. The price is £14 19s 6d (not subject to purchase tax).

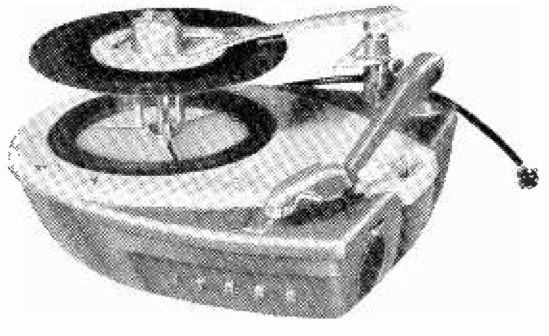
The high-frequency unit is available separately for use with existing loudspeakers and costs £1 19s 6d including purchase tax.

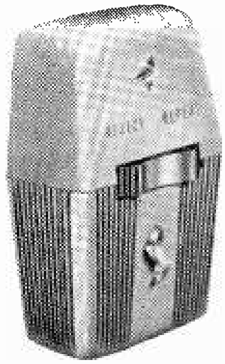
Radio-controlled Record Changer

A NOVEL record player with automatic record changing by remote radio control is to be manufactured in this country by Staar Electronics, Ltd., 39, New Oxford Street, London, W.C.1. It takes up to ten records, has four turntable speeds, including 16 r.p.m. for "talking book" records, and can be used with small or large centre-hole records.

A transistorized unit attached to the record changer receives control signals from a hand transmitter unit (battery operated and also using transistors) and enables the operator to reject or repeat records at will. The output for the pickup can also be made to modulate an r.f. output from the receiver ("transcription unit") which is then picked up by a standard radio receiver or radio-gramophone and reproduced in the normal way. A G.P.O. special transmitting licence for radio controlled devices would be required.

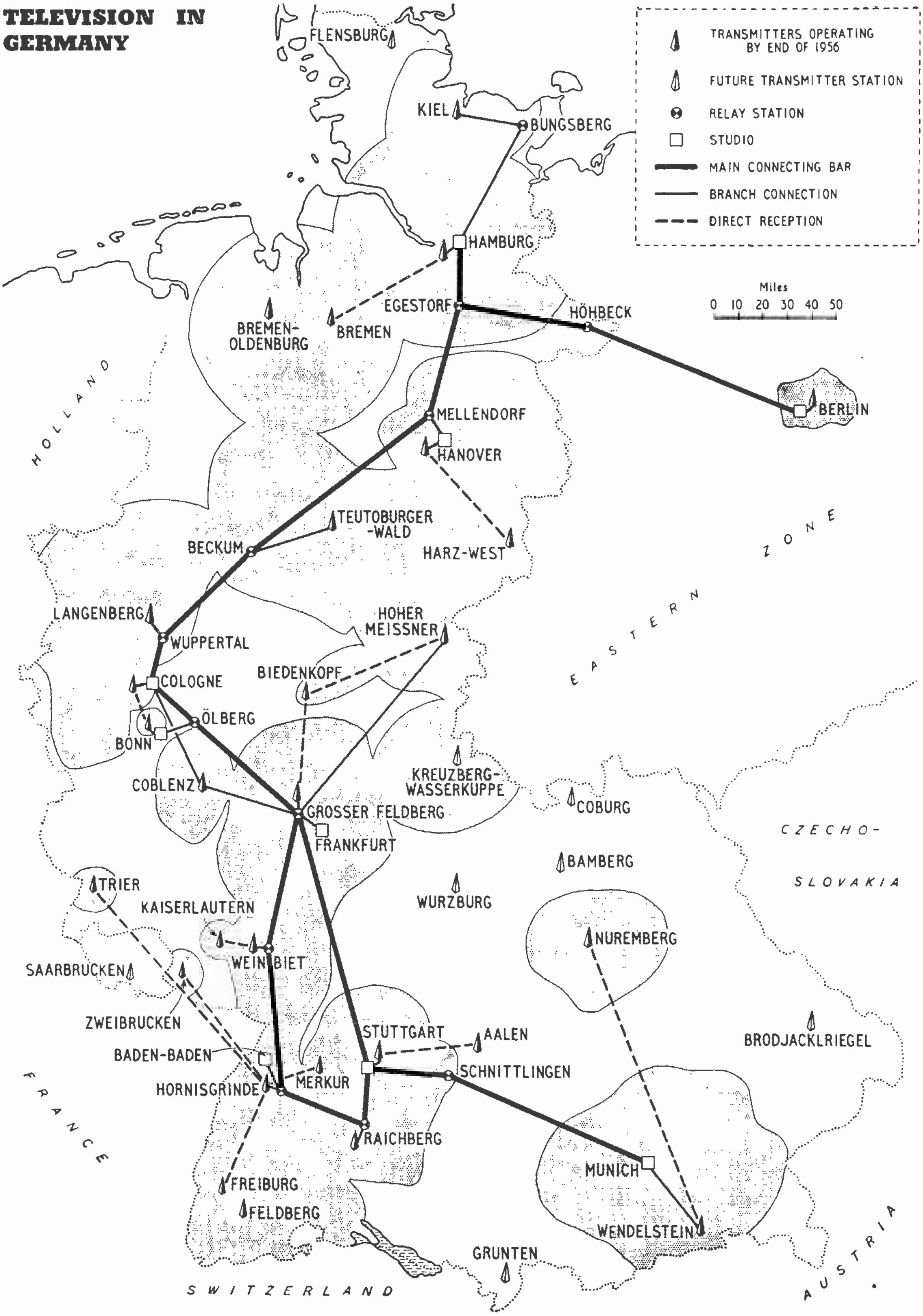






Left: Brayhead 12-channel television turret tuner. Above: Staar Electronics record changer and (right) transistorized radio control unit.

TELEVISION IN GERMANY



Television in Germany

DEVELOPMENT OF THE WESTERN-ZONE NETWORK—AND ITS LINK WITH BERLIN

By W. NESTEL,* Dr. Ing.

ALTHOUGH an experimental television service was established in Germany as far back as 1936 and a public service had been planned for the end of 1939, the war prevented any further development and it was not until Christmas 1952 that television really became fully available to the German people—to those in the West at any rate. Since none of the pre-war 441-line equipment was available it was possible to adopt the new 625-line C.C.I.R. standard. Reconstruction after the war actually began in 1948, and by the time the service opened the Western-Zone network consisted of five transmitters—at Berlin, Hamburg, Hanover, Langenberg and Cologne—and four studios, one in Berlin, one in Cologne and two in Hamburg. Connections between the studios and transmitters were made by radio links.

This represented the first phase of the post-war development scheme. In planning the further extension of the television network, one of the important things which the authorities have had to bear in mind is the regional and de-centralized nature of cultural life in Germany. There is no one town which has a predominating influence in this respect, so it has not been possible to establish a single main centre for programme production as has been done in Britain and France. The system has been arranged, therefore, so that the existing broadcasting companies in the various big towns supply contributions to a joint programme—a principle which is known as *Fernseh-Sammelschiene* or television "collecting bar." Consequently all the studio centres which have been established for sound broadcasting have now acquired extra equipment for the production of television programmes.

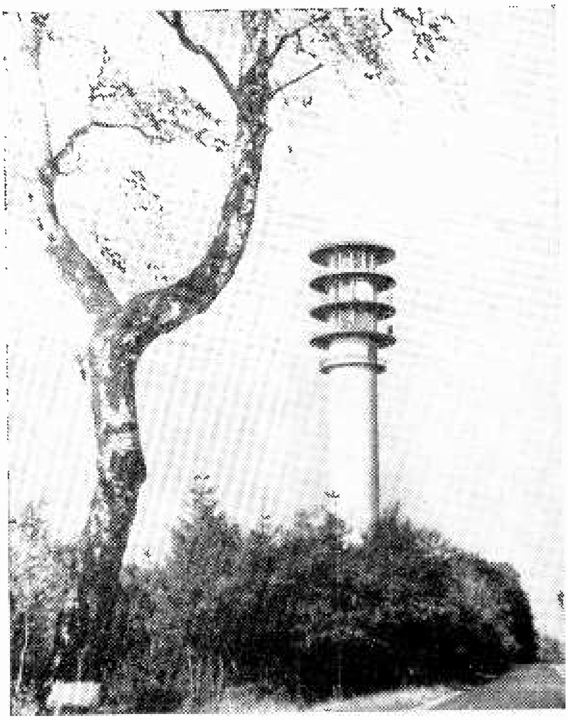
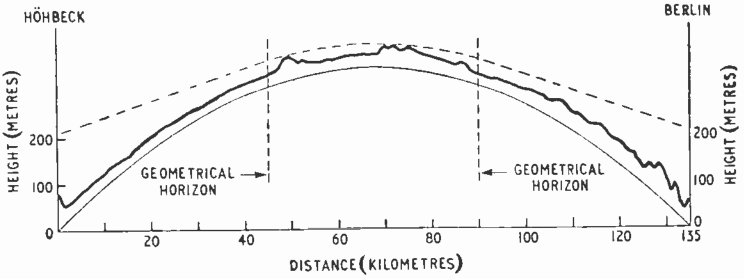


Fig. 2. Decimetre-wave relay station in the "collecting bar" system.

As can be seen from Fig. 1, these studio centres are situated at Berlin, Hamburg, Hanover, Cologne, Bonn, Frankfurt, Baden-Baden, Stuttgart, and Munich. It can also be seen that the television collecting bar is not only a method of operation but a complete chain of radio links (indicated by the heavy black line). As such it will take in programmes from any part of Western Germany, and also distribute the joint programme to the various transmitters. Actually the joint programme only occupies the complete system during the main transmission hours in the evening. Outside of these hours the individual broadcasting companies are at liberty to transmit their own regional programmes, and for this purpose the collecting bar can be split into sections as required.

Most of the radio links in the system work on decimetre wavelengths and Fig. 2 shows a typical relay station housing the directional transmitting and receiving equipment. The link between Höhbeck and Berlin, however, is rather different because it has to pass over nearly 150 kilometres of Russian-occupied territory in a single jump (see Fig. 1). This could not be spanned by decimetre-wave equip-

Left: Fig. 1. Showing the route of the television "collecting bar" in Western Germany, with transmitters and their approximate service areas.



Right: Fig. 3. Cross-section of territory between Höhbeck and Berlin. (The scales in height and distance are not the same, of course.)

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*Nordwestdeutscher Rundfunk, Hamburg.

ment because on these frequencies it is necessary to have relay stations at intervals of about 50 km, so instead a v.h.f. link has been used, working in the region of 200 Mc/s.

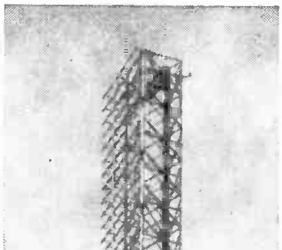
Fig. 3 shows a cross-section of the territory between Höhbeck and Berlin, and it will be seen that the main difficulty is the curvature of the earth acting as an obstacle to line-of-sight propagation. Moreover, this means that the waves have to pass very close to the surface of the earth where tropospheric disturbances can cause severe fluctuations in signal strength. The amplitude of these fluctuations becomes greater the farther the line of transmission extends beyond the geometrical horizon, so it has been necessary to make the radio horizons as far away as possible (that is, as near to the distant station as possible) by using very high masts for the aerials. The masts are actually 492ft high at both ends of the link.

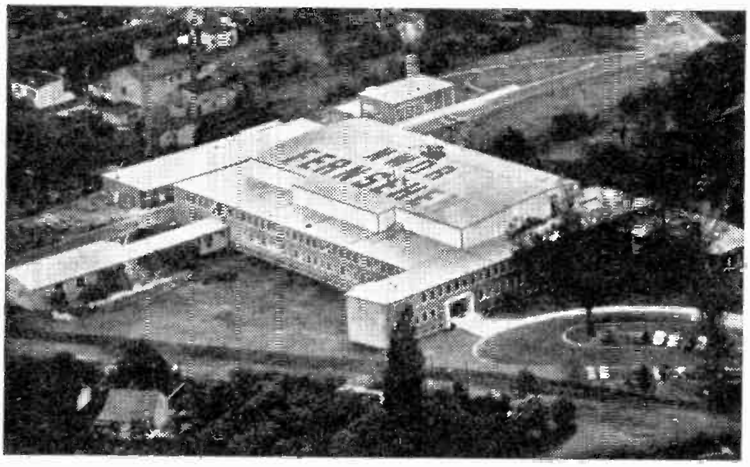
To make sure that the signal strength never falls below the minimum required for reliable operation, the transmitters at both ends (the link is two-way) have the high output power of 10kW, while the directional aerials have the exceptionally high gain (for the 200-Mc/s region) of 500:1. This gives an effective radiated power of 5 megawatts! The transmitters are conventional equipments of the kind used for television broadcasting but the aerials are somewhat unusual, as can be seen from Fig. 4. Each consists of 240 dipoles mounted in groups of eight in front of flat reflectors, and as can be seen from Fig. 5 a very pronounced beaming effect is obtained from the arrangement. The receivers used in the link are specially developed types for relay work, and have a.g.c. circuits, working on the sync-pulse amplitude, which will correct fluctuations of up to 1:10 in the input signal.

Regarding the video equipment of the television collecting bar, each regional centre in the scheme has one studio, a television O.B. van with two or three cameras and a film team using 16-mm equipment. At the two ends of the bar, however, at Hamburg and at Munich, the installations have been made more elaborate so that programmes on a more ambitious scale can be produced. The Hamburg centre, for example, which is in the suburb of Lokstedt, contains three large studios and one small one, together with the appropriate control rooms. If necessary the three large studios can be combined into one by opening the large doors which normally separate them. At Munich the television centre has three studios altogether.

The cameras used in the studios are Super-Iconoscope types requiring a light intensity of nearly

(*Continued on page* 245)





View of the television studios at Hamburg.

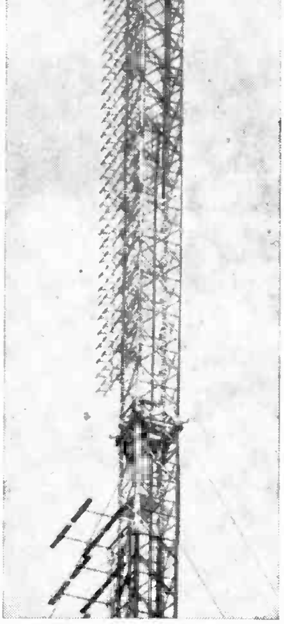


Fig. 4. Directional aerial array of the 200-Mc/s radio link at Berlin.

Right: Typical television O.B. van.

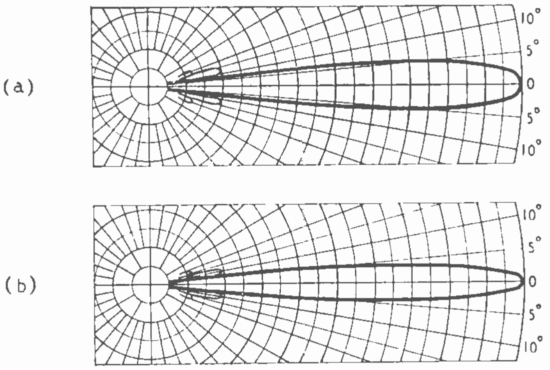


Fig. 5. Polar diagrams showing the radiation patterns, (a) horizontal and (b) vertical, of the directional aerial at Höhbeck.

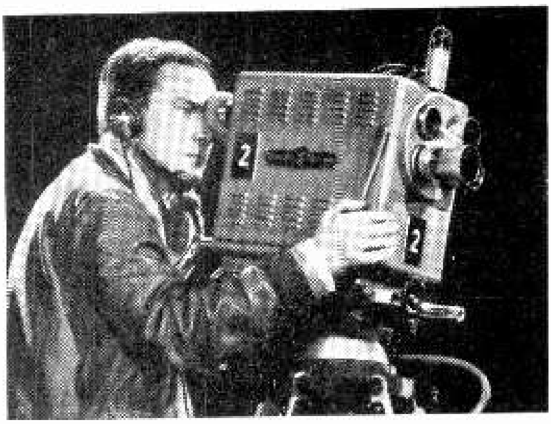


Fig. 6. Super-Iconoscope camera with optical viewfinder.

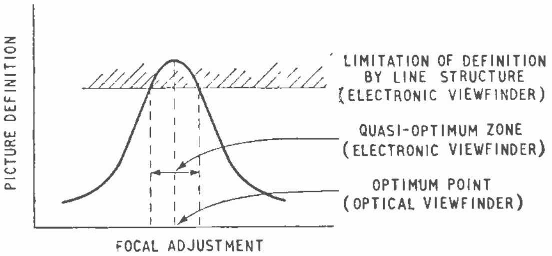


Fig. 7. Curve of picture definition against focal adjustment, showing the limitation on proper camera focusing imposed by an electronic viewfinder.

100 foot-candles for good picture quality, while for outside work Super-Orthicon cameras have been adopted because they will operate with a light intensity of only 5 foot-candles. The first-mentioned types are used, in spite of their great demand for light, because of the more accurate geometrical image reproduction and, in particular, better image gradation. Since the light intensity required in the television studios is about equivalent to that in film studios the performers are quite used to it. With outside broadcasts, however, the picture quality has to take second place to the need for ensuring a transmission of some kind even when the light is very bad. In this work special camera objectives are used which permit a wide variety of viewing angles to be selected, and also vari-optics (made in Britain!) whose focal length can be varied in the ratio of 1 : 5.

The Super-Iconoscope camera made in Germany (Fig. 6) is somewhat different from those produced in other countries. The most notable difference is in the use of an optical viewfinder, and in our view this has a great many advantages over the electronic viewfinder. In the first place the image field is somewhat bigger than the transmitted image and consequently is more helpful in picking out the best viewing angle. Next, the focusing of the camera is improved, since with the electronic viewfinder the line structure tends to obscure the point of optimum focus so that one can never be sure when one is on it. This is illustrated by the diagram in Fig. 7. We also consider it an advantage that the camera operator is solely responsible for the viewing angle and the image definition: the responsibility is not shared between him and the technician at the camera amplifier, as with the electronic viewfinder.

Another point is that the brightness of the optical viewfinder picture varies in accordance with the exterior brightness, whereas the constant brightness of the electronic viewfinder picture is too poor in sunlight and too intense in dark rooms. Finally there is the smaller number of component parts in the optical viewfinder, which makes for greater reliability and also a reduction in size and weight. These advantages seem so important to us that we cannot understand why such uncritical preference is given everywhere to the electronic viewfinder. In the author's opinion, the electronic viewfinder is of importance only in cameras equipped with vari-optics.

During the three years that the television service has been running a good many technical improve-

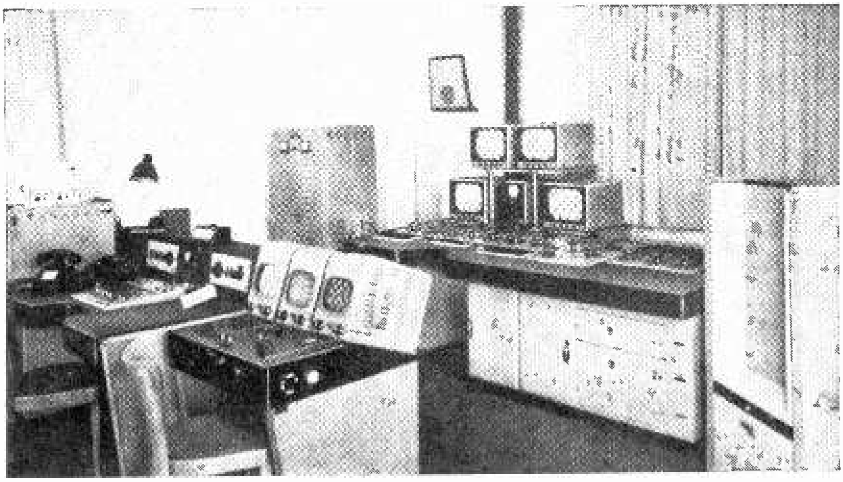


Fig. 8. Control centre at Cologne for Eurovision.

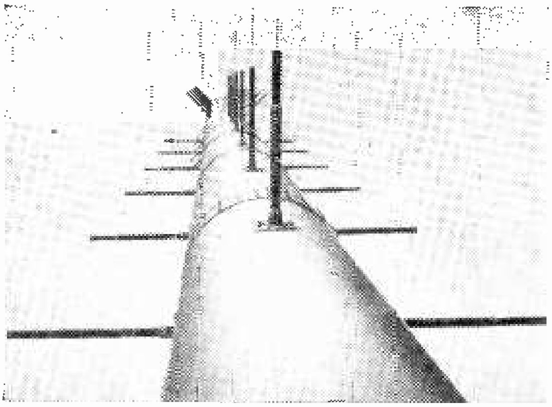


Fig. 9. Combined television and v.h.f. sound aerial of the Teutoburger Wald transmitter.

ments have been introduced. Among these the differential equalizer, which was brought in following the example set by the B.B.C.,* is particularly worth mentioning. Another type of correction has been introduced in the transmitting equipment to compensate for the phase distortion in receivers (to which the picture is very sensitive) caused by the vestigial-sideband and selectivity characteristic of the i.f. response curve. In the television collecting bar system a control centre has been set up at Cologne (Fig. 8) specially for Eurovision programmes, and this contains a standards converter for converting foreign standards into our 625 lines.

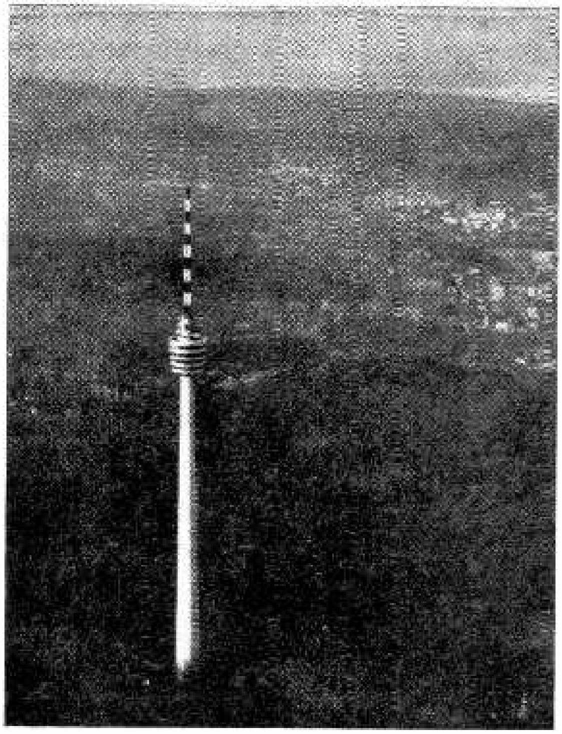


Fig. 10. The Stuttgart television and v.h.f. tower. Total height is 690ft while the "crow's nest" is 50ft in diameter

The control centre at Cologne, incidentally, consists of three rooms, one being for technical operations and another for programme arrangements, while the third is a studio for making announcements and giving commentaries. The technical operations room is equipped with a picture switching desk handling all the necessary inputs and outputs, mixing desks for vision and sound, and 20 television sound and control lines with the appropriate telephone and switching devices. There are also two 35-mm film scanners, a slide scanner, monitoring and test equipments, a teleprinter and a spare power supply. On some occasions this control centre has taken over the job of the Eurovision co-ordination centre at Lille when this has been necessary for technical or staffing reasons.

Coming now to the transmitters, most readers will probably be aware that the majority of German television transmitters operate in Band III in the region of 200 Mc/s. There are, however, a few stations operating in Band I. Fig. 1 shows the present transmitters and their service areas and also includes the transmitters which are expected to be in operation by the end of the year (with their estimated service areas). The other transmitters, shown without service areas and not linked to the "collecting bar," will not be ready for some time yet. At present some 70 per cent of the population live in districts where good reception is obtainable. When the extension planned for the end of 1956 is completed about 80 per cent of the population will be provided for. A further extension will be necessary to fill in the last few blank spaces on the map, and it is likely that a new frequency band near 500 Mc/s will be used for this, as well as for a possible alternative programme.

Incidentally, it proved to be a great advantage in the construction of the television stations that the transmitting technique, network planning, choice of sites and use of aerial masts could be coupled with the v.h.f. sound broadcasting network completed only a short while beforehand. Fig. 9 gives an example of this, showing how the aerials for television and v.h.f. sound are combined into one.

From the point of view of mechanical design the Stuttgart station near Degerloch is particularly interesting. It is a tall tower 530ft high (see Fig. 10) with a four-storey "crow's nest" on top which contains the transmitters and a restaurant, surmounted by the 160-ft lattice aerial mast.

At the receiving end, the development of the last three years has resulted in a considerable reduction in receiver prices because of the increasing number of sets manufactured. At the same time the average size of screen has increased from the 14 inches diagonal originally preferred to 17 inches, while quite a large number of receivers even have screens of 21 inches. Projection receivers for hotels giving 3ft-wide pictures and for cinemas giving 13ft pictures are also on sale. On the occasion of the German Radio Show at Dusseldorf in 1955 the industry showed what it could do, while the public demonstrated its increasing interest in television. At present some 290,000 receivers are in operation—and this does not include all the sets for which no licences have been taken out. In a few years' time we have every hope that the number of viewers will reach the 5 million mark as in Great Britain at the moment. At any rate, television techniques in Germany are prepared for it, at both the transmitting end and the receiving end.

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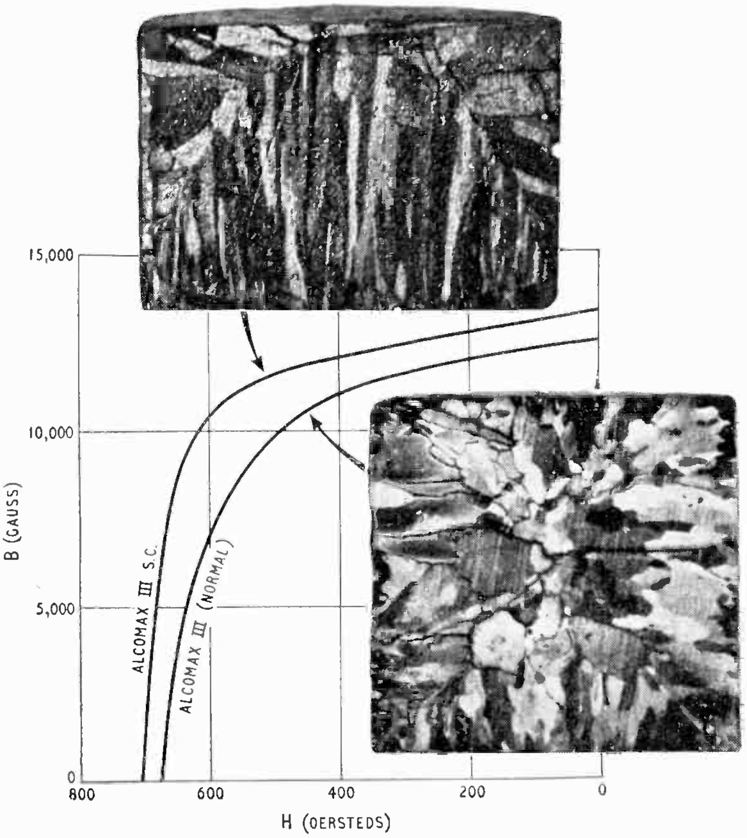
*G. G. Gouriet. "Spectrum Equalization," *Wireless Engineer*, May 1953.

NEW MAGNETIC MATERIALS

A RANGE of permanent magnet materials having properties intermediate between Alcomax and Columax has been introduced by the Permanent Magnet Association. It will be remembered that Columax is an alloy which has a columnar crystalline structure and the highest performance of any known p.m. material; but it is difficult to produce economically in large quantities.

The new materials, Alcomax S.C., are semi-columnar and can be produced in short cylindrical shapes from ¾in diameter upwards for use in loudspeaker magnets.



Typical magnetization curves for normal Alcomax III and Alcomax III S.C., together with etched sections showing their crystalline structure.

FARADAY CIRCUS?

ALTHOUGH there are memorials to Michael Faraday at the Royal Institution, the I.E.E. and in Westminster Abbey, there is no memorial to him in the Borough of Southwark where he was born. With the redevelopment of the area including Newington Butts—his birthplace—it is proposed to name an important road junction nearby after him and to erect a memorial. A committee of representatives of various institutions, including the I.E.E., the Faraday Society and the Royal Institution, has therefore been set up to investigate the most desirable kind of memorial to be erected.

It can perhaps be claimed on Faraday's behalf that he propounded the fundamental principle of radio. In a letter, deposited at the Royal Society in 1832 "to take possession as it were of a certain date" should his views be confirmed by experiments, he wrote "Certain of the results of the investigations . . . lead me to believe that magnetic action is progressive, and requires time; i.e., that when a magnet acts upon a distant magnet or piece of iron, the influencing cause (which I may for the moment call magnetism) proceeds gradually from the magnetic bodies, and requires time for its transmission which will probably be found to be very sensible. I think also, that I see reason for supposing that electric induction (or tension) is also performed in a similar progressive way. . . ."

RANDOM RADIATIONS

By "DIALLIST"

Ally Pally

IT'S HARD to realize that it's twenty years all but a few months since the Alexandra Palace station started the world's first high-definition television service. But twenty years it will be, come November. Old hands (and even some of the not-so-old ones) may recall that it began with two rival systems on trial. One was the Baird with sequential scanning and the other the Marconi-E.M.I. using line interlace. Each concern installed its own transmitter and for some little time they were used alternately for periods of a week. There wasn't then any Sunday television. Eventually, the interlaced scan was found to give the better and less flickery picture and sequential scanning dropped out. Note that I wrote "the first high-definition television service." The first television transmissions were actually made a good few years before that on London's 9-kc/s sound broadcasting channel by means of the original Baird 30-line scanning-disc system. The real image was quite tiny, but a lens increased its apparent size to something like that of a quarter-plate photograph.

A Good Start

The London television station is outside my receiving range now; but from what one hears the new station at the Crystal Palace seems to be fulfilling expectations, to say the least of it. Many with older double-sideband receivers who didn't expect to get an acceptable picture are more than satisfied with the results. Naturally, it'll take a bit of time to get things sorted out: lots of viewers, for example, probably forgot to have their aerials reoriented. The fact that the coverage is so good with a "jury" mast and an e.r.p. of only 60 kilowatts shows that wonderful results should be obtained when the permanent 640-foot tower comes into use within the next 12-18 months and the e.r.p. eventually goes up to 200 kilowatts.

Electronics on Show

HOW MANY exhibitions are there each year in London alone in which radio and kindred electronic gear are shown? Besides the National Radio Show, I can think right away of the R.E.C.M.F. Exhibition, the Television Society's, the Physical Society's, the S.B.A.C. (Farnborough), the Ideal Home, B.I.F., Electrical Engineers' Exhibition, the Motor Show and the Marine and Shipping Exhibition. And there are probably several more. It does seem an awful lot when you come to think of it; but I suppose it's worth while to have so many. At some of them, of course, specialized forms of apparatus are on view: aircraft radio at the S.B.A.C. show, marine radar and communication equipment at the Shipping Exhibition, and so on. Exhibitions are some of the manufacturers' best shop windows, for they attract so many potential buyers from abroad as well as from this country.

Clearing Band III

THE allocation of Channel 10 to the Yorkshire I.T.A. transmitter on Emley Moor shows that some progress is being made in the clearing of Band III for television. The P.M.G. has told us that he hopes to have two more Band III channels (making five in all) free reasonably soon. But the authorities concerned will really have to get a move on if they're really anxious for I.T.A. to expand as rapidly as possible. I.T.A.'s plans include at least two stations to be opened during next year. These are Scotland and South Wales. Both the Authority and the dealers and viewers in the districts concerned need to know which channels will be assigned to particular areas so that they can plan accordingly. And it's *rather* important that those who manufacture aerials should know what channels they have to cater for.

Suppressors That Don't

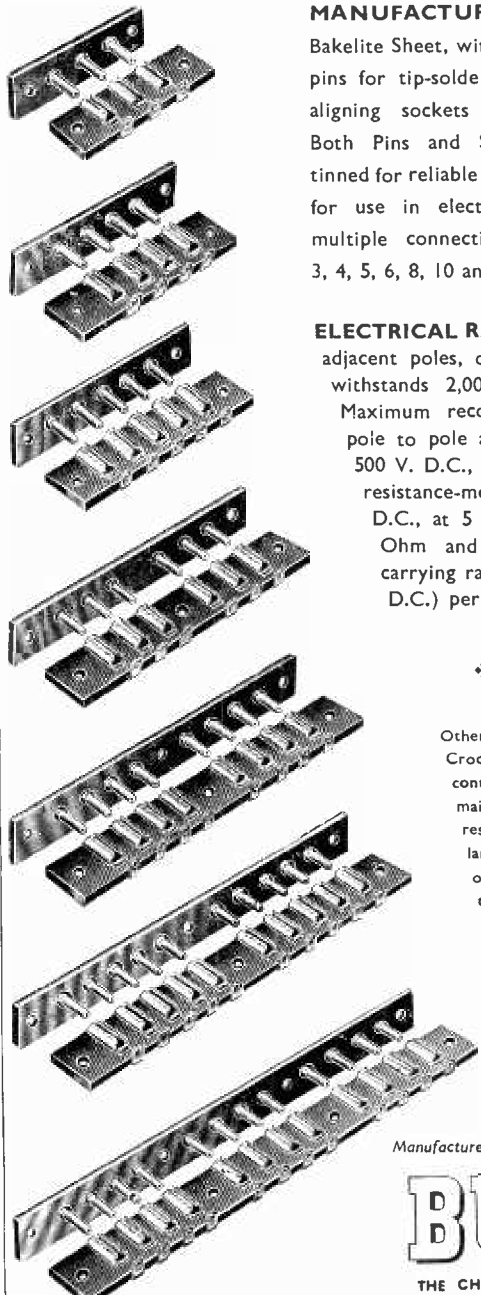
MOTOR VEHICLE ignition interference doesn't seem to me to show any signs of decreasing; in fact, I'm inclined to think that it's becoming heavier and more annoying than ever. The law obliges all new vehicles to be fitted with suppressors; yet a good many of those of quite recent date cover the TV screen with lines of interference as they pass. Have the suppressors been removed? Or aren't they of the right kind? Ineffective suppressors are sometimes fitted by manufacturers to various domestic electrical appliances. It's rather a shock to the purchaser of a gadget, which is stated to be suppressed, to receive, soon after he (or more often she) starts to use it, a visit from someone suggesting that they are causing quite a bit of interference. The wise person does not buy such things without first insisting on a demonstration to prove that they don't cause interference.

Adaptors and Convertors

The P.O. is showing signs of getting tougher in the matter of interference with television reception from sets which were either unsuitable for conversion, or have been fitted with unsuitable Band III adaptors or convertors. In some areas, at any rate, people have been told that they'll be for it if they continue to use such sets for Band III reception. Dealers should, I feel, be more cautious about carrying out adaptation jobs. It doesn't do them much good to have customers who, after spending a tidy sum on having their sets adapted, find that they can't switch on the I.T.A. programmes without arousing the wrath of their neighbours.

Radar Progress

WHAT enormous strides radar has made since it was first developed by the "back-room boys" of Bawdsey and christened R.D.F. The first Army equipment, GL1, could measure only range and bearing and it wasn't at all an easy thing to use. The Bedford attachment for measuring the angle of elevation (and so enabling the height of an aircraft to be found) wasn't in anything like general use until about a year after the start of the war. Then came GL2, which was a vastly better outfit, though it had the drawback of containing far too many mechanical bits and pieces—gear trains and suchlike—in its innards. Both of these GLs were metre-wave equipment; but GL3 and its successors used the then newly developed cavity magnetron and wavelengths dropped to the centimetre region. Automatic following was the next big advance and that has now been brought to such perfection that, once you've selected your target, you just lock the instrument on to it and it does the rest. Some years ago Sir Edward Appleton suggested that one day we might have what he termed "radar - television": you wouldn't just see a "blip" on the screen; you'd see the target ship or 'plane so clearly that you could identify it. Marine radar can already give such clear pictures of coastlines, harbours and so on that we've gone quite a way towards radar-television.



UNBIASED

By FREE GRID

Presbyotic Problems

IT IS an astonishing thing how few cinemas provide special phone-fitted seats for people who are hard of hearing. One manager with whom I raised the question said they were not needed now that good hearing aids are available through the N.H.S. I could not agree less. My own hearing is far from 100 per cent and I have often compared listening to B.B.C. programmes with a conventional hearing aid and with a pair of earpieces coupled direct to the output of the set. The latter is very much the better.

In fact, the use of a modern hearing aid which is excellent for ordinary conversational purposes does not give me such good results as does an old-fashioned ear trumpet directed at the loudspeaker. Perhaps some of you acoustics experts can tell me why. The result is that when Mrs. Free Grid and I go to a friend's house in the evening I invariably take my ear trumpet with me in case we are invited to look at or listen to some special programme.

My ear trumpet naturally excites ridicule and jokes about approaching senility which are not made when an electrical hearing aid is used. As for signs of approaching senility, surely everything in life is that, including the cutting of a baby's teeth and the growing of its hair which do not happen until it has moved a little along the road from the cradle to the grave.

I think the loss of fidelity, when listening to a loudspeaker with a hearing aid stuck in front of it, arises because the signals, having just been converted from electrical to acoustic energy, have once more to be re-converted to electrical impulses by the hearing-aid mike and then again turned into acoustic ones by the earpiece. This extra conversion is the last straw which breaks the camel's back.

I have successfully solved the problem in my home by adopting the new technique of concealing a metal conductor fixed around the room and using a pair of induction earphones. Surely cinemas and churches too should be fitted with a conductor fitted on the backs of all seats. In many buildings having nasty echoes and poor acoustics generally, even those of normal hearing would welcome this.

Transistorized Telearchics

I AM interested to hear that a record changer is to be marketed which can be remotely controlled by a transistor transmitter small enough to be held in the hand. The firm responsible for this is also to market a radio gram—not to be confused with an ordinary one-word radiogram—in which there is a wireless link between the record player and the amplifier. Maybe the two instruments will be combined.

Basically the two ideas are not new, but this practical application of them in modern form most certainly is. I would have liked to buy one of these new instruments—but one thing deters me and that is this. The range of the small transmitter is said to be 25 *yards*. But only a few *feet* separate me from my neighbour on the other side of the party wall. Thus if he objected to my playing Sousa in full blast he would only have to buy one of these new instruments himself and use its transmitter to turn off my record player. In fact it could develop into a duel of rapid fire between our two pistol-grip miniature transmitters; in-out, in-out, like a French government.

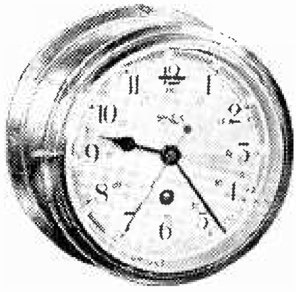
Worse than that, the transmission from my radio record player would pass through the party wall and could be used to operate the amplifier part of his instrument. Thus he could just sit back with a tankard of beer and enjoy himself at my expense, leaving me to shoulder the cost of constantly getting new records; with L.P. ones at 35s apiece he would save no mean sum of money.

My ear trumpet excites ridicule.

Even if the makers arrange that instruments sold to neighbours be adjusted to slightly different frequencies, as I expect they will, my own neighbour could easily find out my frequency and adjust his instruments accordingly. I can see no solution save the unæsthetic one of lining my walls, ceiling and floor with earthed wire-netting and I hope the manufacturers will supply a roll of it with each instrument they sell.

Three Minutes' Silence

WHILE at the B.I.F. I noticed among the exhibits of Smith's, the well-known firm of clock makers, one of those timepieces with specially marked dials for use in ships' wireless cabins. They have two red segments which at their circumferential end extend from the 15th to 18th and the 45th to 48th minutes after the hour, respectively.



Radio officer's timepiece.

These are the periods when ships' transmitters are intended to keep silence in order to enable a careful look-out—or more correctly, listen-in—to be kept for distress signals and the red segments are to remind the operator to stop transmitting.

One of the firm's representatives on the stand, noticing my interest in these clocks, told me in very sarcastic tones that the red segments were really only ornamental as few operators at sea bothered to observe these periods of silence. I have heard this criticism before, but, while there are undoubtedly some black sheep afloat, I don't think that the non-observance of this silence is entirely the operators' fault.

At a time when operators are busy handling heavy traffic surely it is all too easy for them to overlook the approach of the 15th and the 45th minute of each hour. Surely the fault lies with higher authority who should call upon the clock manufacturers to do something better than paint these clock faces like those of Mrs. Free Grid and her friends when going out for an evening.

The proper remedy is to fit the clocks with simple electrical contacts so that a warning signal could be injected into the operator's earphones. This, I feel sure, would make all the difference in the world and would really result in a deep and dramatic three minutes' silence at sea every half-hour, as is intended by the international regulations.