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Wireless World

Colour Fiasco

TWO months ago *Wireless World* expressed fears that the B.B.C. demonstrations of colour television which had recently been given might well have proved too successful. There was a risk that the high quality of the pictures transmitted and received under strictly experimental conditions might have inculcated a widespread idea that the N.T.S.C. system used for the tests was good enough for a regular service for reception in the home. It would now seem we were not emphatic enough in urging that a decision to adopt the system for this country would be disastrous.

During the last few weeks many reports have come in from British observers of the highest competence on the failure of colour television in America. With singular unanimity, all the reports coming to our notice tell the same doleful story; technically, economically and industrially, the N.T.S.C. system is failing to live up to the high expectations expressed when it was first introduced. Indeed, there now seems to be a widespread lack of enthusiasm for colour in the U.S.A., and the reported change in attitude of R.C.A. appears to be particularly significant. Some views of British observers are summarized on p. 205 of this issue.

In spite of the growing tale of woe from America there is still a school of thought in this country which says, in effect, " Admittedly the N.T.S.C. system may have its weaknesses, but perhaps they can be overcome. In any case, nothing better offers itself at present; unless we adopt it there is no possibility of starting a British colour service in the foreseeable future." That attitude seems to represent an attitude of despair: *Wireless World*, resisting the temptation to make the vulgar retort " So what?" will merely offer the quotation: " The lesson of history is that mankind learns nothing from history."

That is not to say the B.B.C. experimental colour transmissions should cease; still less that research on the general problems of colour television should not be pressed forward as actively as national resources will allow.

We must go on trying to find basically new methods. But, to start even a restricted and experimental public service of regular N.T.S.C. transmissions at the present state of development would surely be a deplorable error.

The Television Advisory Committee is expected to issue a report before very long; it will be surprising—and disappointing—if the Committee does not reach the conclusion that further basic development is needed before any specific recommendation can be made on the colour system to be adopted for Great Britain.

Editorship of "Wireless World"

THIS intrusion on a page usually reserved for the Editor's comment is explained by saying that it is now the Editor himself who is to be the subject of comment.

The present Editor, H. F. Smith, is vacating the editorial chair in May after 46 years in radio and 32 years on *Wireless World*. For over half that period he has been Editor and it may be said that since 1940 the journal has revolved around him as its axis.

This is a long span of service on a technical journal of any kind, and it is noteworthy that in our particular sphere the period covered has seen greater scientific progress and technological development than has ever been witnessed before in any branch of science.

To have conducted *Wireless World* during such a time with so much distinction is in itself a sufficient tribute to the retiring Editor, but we know that in addition his personality and his readiness to share his experience and knowledge with others has gained him a multitude of friends all over the world.

It is at his own wish that he is relinquishing the editorship on attaining the normal retiring age, but happily his connection with *Wireless World* is not to be abruptly severed, and he has been persuaded to continue for a time in a consulting capacity. He is to be succeeded as Editor by F. L. Devereux, who has a long and distinguished record of 33 years with *Wireless World*. H.S.P.

French Components Show

THE radio exhibition held annually in Paris under the impressive title "Salon National des Fabricants de Pieces Détachées Radio, Accessoires, Tubes Electroniques et Appareils de Mesures," embraced a far wider field than hitherto and thus afforded an opportunity to assess the progress of development of a large section of the French radio and electronics industries.

So far as components are concerned the trends are very similar to those in Great Britain. Considerable progress has been made during the past year in the manufacture and application of transistors and several firms are now producing transistorized broadcast receivers, as typified by the C.S.F. "Translitor." This company also showed transistor power supply units, interchangeable with the normal batteries, for military "Handy-Talkie" sets.

An interesting application for transistors was shown by Teppaz in the form of an a.c./battery record player. It has an 8-V synchronous motor, normally operated from the electric supply mains through a step-down transformer. For portable operation the 50-c/s supply for the motor is provided by a transistor oscillator taking d.c. power from a battery and using the motor windings for coils.

A number of new semi-conductor devices were shown by the French Thompson-Houston Company; one was a 2.5-W a.f. power transistor, and another a silicon-junction diode rated at 1.5 A at 50 c/s.

The use of solar power for operating transistor equipment was demonstrated by Westinghouse with a Zenith pocket receiver powered by 144 "Westaphot" cells and a floating 4.8-V battery. This supplied 10 to 20 mA of current.

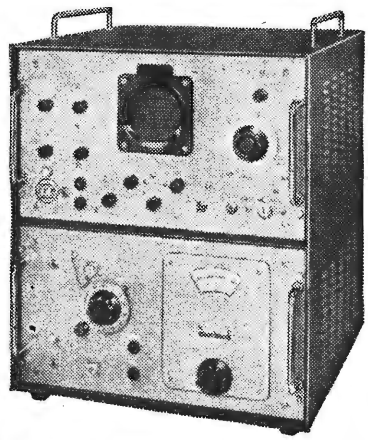
A new covering for instrument wires, described as "Carafil," was shown by S.C.F. It is very resistant to high temperatures and enables current loadings heavier than normal to be imposed on transformers and chokes, thus resulting in some reduction in size and weight.

Printed circuits are beginning to find applications in French electronic equipment, but there is little evidence that dip-soldering is in general use.

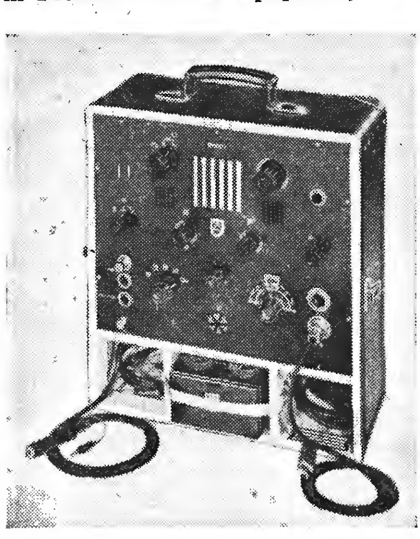
For some years past adjacent-channel interference on the broadcast bands has been combated by using rotatable frame aerials and many French receivers embody this feature; ferrite loops being the popular kind. F.M. has not, therefore, had the same attraction in France as an interference-reducing medium for broadcast; nevertheless f.m. sets and parts were well in evidence.

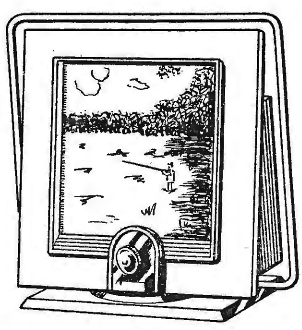
Radio-Celard of Grenoble combines the f.m. and loop-aerial solution to interference in the "Captefem" adaptor. This consists of an f.m. unit with a rotatable loop aerial feeding into the pick-up terminals of the broadcast receiver. On medium and long waves the loop is used as a low-impedance frame aerial followed by an r.f. stage and its output fed to the aerial terminal of the receiver.

The French electronics industry is now producing

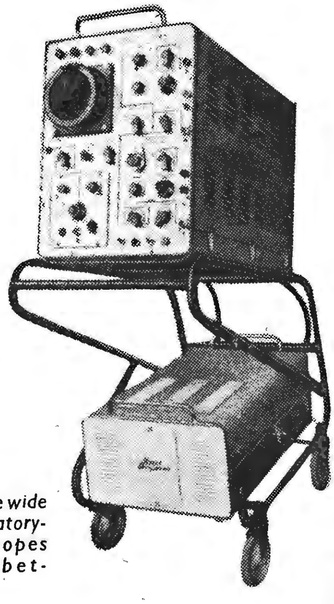


Above: "Spectrum Analyser" shown by Derveaux for general radar testing.



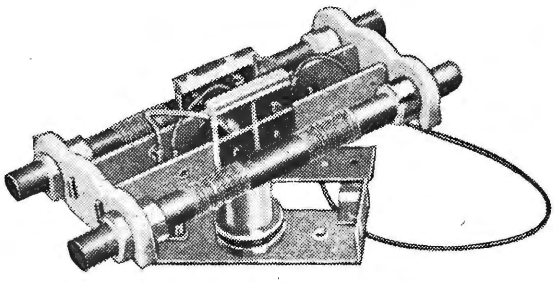


"Captefem" f.m. adaptor with rotatable loop aerial (Radio-Celard).



Left: Philips combined pattern generator and signal tracer covering television Bands I and III.

Right: One of the wide range of laboratory-type oscilloscopes shown by Ribet-Desjardins.



Transco rotatable ferrite rod aerial.

a variety of test and laboratory equipment. For testing transistors, for example, C.R.C. have introduced the "Transigraphe GP70" which displays the family of curves for a p-n-p or n-p-n transistor directly on a c.r. tube. An optical attachment enables the displayed curves to be traced, by hand, on paper. Derveaux had a range of radar test sets covering 20 cm down to 8 mm, as well as a new spectrum analyser for general radar work. Ten different types of laboratory oscilloscope were shown by Ribet-Desjardins, the most elaborate going up to 50 Mc/s, having sweep speeds up to $\frac{1}{100}$th μsec, electronic switching and a delay line.

A.C. milli-voltmeters with input impedances between 10 kΩ and 1 MΩ and usable from 20 c/s to 100 kc/s, were shown by Ateliers DA et Dutilh. They employ a form of transistorized valve voltmeter with a 6-V dry battery.

Television service equipment was represented on Philips' stand by an interesting combined portable signal generator covering Bands I and III and the customary i.f.s., and a signal tracer with loudspeaker. Equipment for testing bilingual TV speech channels, a system evolved for use in North Africa (see *Wireless World* Technical Notebook, February and March 1957), was shown by Société S.I.D.E.R.

Colour TV in the Doldrums

THE general impression that American colour television is a complete failure was confirmed recently by C. O. Stanley, Chairman of Pye's, in an interview with *Wireless World* on his return from a visit to the U.S.A. One of the main reasons for the situation, said Mr. Stanley, was economic. Americans were not prepared to pay more than about 10 per cent above the cost of black-and-white receivers for colour sets—whereas in fact the colour sets were priced at 500 dollars (and subsidized at that) compared with the 160 dollars of equivalent monochrome receivers. The discrepancy was made worse by the fact that monochrome sets were falling in price anyway as a result of fierce competition and "distress merchandizing."

A second important reason for the situation was the poor technical quality of the pictures given by the N.T.S.C. system, especially in fringe areas and at the extremities of transmission networks. This applied to both colour and compatible black-and-white pictures. As a result, one could not help feeling that some American engineers were now beginning to doubt the wisdom of their having adopted compatibility in the first place, if one of the consequences was a loss of audiences to the broadcasting stations. Added to all this were the considerable difficulties of receiver adjustment and servicing—it was being said that an M.I.T. engineer was needed with every set installed! The actual programmes—about three hours per day—were, however, very good indeed.

The only real force behind colour television in America recently had been RCA, said Mr. Stanley, and one could not fail to observe that this organization had its plate full with some very serious lawsuits. At the same time, a business efficiency expert had been appointed president, and it might well be that the heavy financial leak due to colour television might stop RCA's interest in this project. If this happened it would put colour television on the ice for a considerable time.

On the question of single-gun tubes for receivers and other new components which would be required, it appeared that while the industry was in the doldrums in America nobody could spare the money to develop them—and the somewhat different receiver circuitry—for large scale production. The story might have been different had there been more time and freedom for independent lines of investigation into systems and display devices at the very beginning—but the over-hasty decision to get colour television going at all costs had now "queered the pitch." At the moment, it did not appear that single-gun receivers could be made any cheaper than those using the three-gun tube.

The American example, said Mr. Stanley, was a clear lesson to us that we ought to stop thinking about setting up a public service in Britain, and treat colour television purely as a laboratory problem. A satisfactory colour receiver could not at the moment be sold for less than £200 (excluding P.T.) and there was no reason to believe that British people would pay a greater proportion more for colour than the Americans—especially during the present period of rising prices.

These views were confirmed by L. C. Jesty, of Sylvania-Thorn, speaking with Dr. E. L. C. White at a recent I.E.E. informal lecture on colour television. He said there was practically no technical activity in the U.S.A. at the moment and no reference to colour in the recent I.R.E. Convention—except an account of what was happening in Europe. Mr Jesty's estimate of the desirable maximum price of a colour set was, however, somewhat higher than Mr. Stanley's—not more than two-thirds above the cost of a monochrome receiver.

It was generally agreed by other speakers that very little could be done until a really cheap and satisfactory colour display device had been evolved, and consequently all the present work on transmission systems could only be regarded as academic. One speaker in particular compared the progress of colour television with the history of colour photography and prophesied on that basis that we still have a long way to go. "We are now nearly through the era of the three-gun tube" he said—although Mr. Jesty had remarked earlier that the three-gun tube was still the backbone of colour television in the U.S.A.

WORLD OF WIRELESS

International Acoustics Meetings

TWO recent Paris meetings of international committees dealt with acoustics. Among the subjects discussed at the meeting of the electro-acoustics committee of the International Electrotechnical Commission were lateral-cut commercial and transcription disc recording, methods of measurement of the electro-acoustical characteristics of hearing aids, sound systems, loudspeakers, ultrasonic therapeutic equipment, and sound level meters. The eleven-man British delegation was led by R. S. Dadson (N.P.L.), and consisted of J. P. Ashton (Amplivox), R. A. Bull (Westrex), H. Davies (B.B.C.), Dr. G. F. Dutton (E.M.I.), N. Fleming (N.P.L.), S. Hill (S.T.C.), Dr. A. J. King (Metrovick), Dr. W. Summer (Barber Electrical Services), F. E. Williams (Post Office), and A. D. Falk (B.S.I.).

The second meeting, attended by delegates from 14 countries, including seven from Britain, was concerned with physical acoustics. A definition of the phon was agreed upon and will be circulated as a draft I.S.O. (International Organization for Standardization) recommendation. It is similar to that proposed some 20 years ago but never ratified.

Phenomenal Television Reception

NORMAN BURTON reports from Revesby, N.S.W., Australia, that since October last he has heard the B.B.C. television sound on 41.5 Mc/s some twenty times and the vision signal three times. On one occasion in November the vision signals were on peaks as strong as the local television station. Reception was confined to the 11 a.m. to 1 p.m. morning session of the London station and the B.B.C. has verified one transmission from a tape recording. Unfortunately the recorder was not always available and generally missing when signals were at their best.

The receiver was a Hallicrafter SX28 and the aerial, a 2-element one, constructed from details published in the August 1947 *Wireless World.*

Marine Radar Training

COMMENTING in our December 1956 issue on what have been somewhat ironically called "radar assisted" marine collisions, we stated "as far as we know there has never been a case of collision which could be contributed to failure or lack of accuracy in the equipment itself. . . . By far the most prevalent cause of error is faulty appreciation of the displayed information." A step toward ending this unfortunate position has been taken by the Ministry of Transport and Civil Aviation by the introduction of a new regulation. It makes it compulsory for a deck officer in the British marine service to take an officially approved radar observer course before being issued with a certificate of competency as second mate (foreign-going) or mate (home trade).

The new regulation comes into operation on June 1st.

Scottish Exhibition

THE biggest United Kingdom domestic sound and television exhibition yet held outside London opens at Kelvin Hall, Glasgow, on May 22nd for ten days. There will be nearly 60 exhibitors, including all the leading domestic receiver manufacturers. It may well provide a preview of the National Radio Show to be held at Earls Court in the autumn.

Although there will be considerable emphasis on television—about 100 receivers will be operating on the stands—the B.B.C. technical *pièce de résistance* will be a demonstration showing the benefits of v.h.f. sound broadcasting.

1958 Exhibitions.—Soon after the list of exhibitors for the 1957 I.E.A. Exhibition had closed the date of the 1958 Show was announced—April 16th to 25th at Olympia. An Electronic Computer Exhibition, to include data handling equipment of all kinds, is being organized jointly by the Radio Communication and Electronic Engineering Association and the Office Appliance and Business Equipment Trades Association for November 28th to December 4th next year at Olympia.

Television Duty.—The additional £1 to be charged for television licences in August will not bring extra money to the B.B.C.; it is an excise duty added to the licence fee. Incidentally, under a new agreement which came into operation on April 1st, the B.B.C. will in future receive 87½% of the licence revenue after the Post Office has deducted "a sum equal to the expenses incurred by the P.M.G." in collecting the licence fees and investigating interference complaints.

B.B.C. Television Service.—When by the end of the year the B.B.C. has achieved its objective of providing a television service to 98% of the population, it will then set about building "fill-up" stations for places within the general coverage area where reception is inadequate —such as Peterborough and Berwick. The Corporation will then extend the service to the highlands and islands outside the main service areas.

Hearing Aid Production.—As "purchasing agent" for the Ministry of Health, the Post Office has bought 800,000 "Medresco" hearing aids and 27M batteries for them since 1948, when the Dollis Hill Research Station produced the prototype. The Contracts Department of the Post Office also arranges for the repair of some 120,000 hearing aids a year.

Broadcast receiving licences in force in the United Kingdom at the end of February totalled 14,480,562. Of this number, 6,863,234 were for television and 304,307 for car radio sets. During February television licences increased by 106,049.

Heaviside Lived Here.—Among a number of plaques to be erected by the London County Council to mark the former homes of famous people is one recording that Oliver Heaviside lived at 55, Plender Street, St. Pancras, London, N.W.1.

Purchase Tax on domestic sound and television receivers contributed over £40M to the national income in 1956.

Webbs Radio ask us to correct the price of the Eddystone 820 f.m./a.m. unit quoted in their advertisement on page 126. It should be £31 18s.

West Wales will have a television service and a three-programme v.h.f. sound service from April 29th when the B.B.C.'s station at Blaen Plwy, near Aberystwyth, is introduced. The television station, operating in Channel 3 (vision 56.75 Mc/s, sound 53.25 Mc/s), started test transmissions on April 15th. It has an e.r.p. of 1 kW and will serve the coastal belt around Cardigan Bay. The v.h.f. sound transmitters will radiate on 88.7, 90.9 and 93.1 Mc/s, each with an e.r.p. of 60 kW. Aerials for both services are mounted on a 500-ft mast, and the transmissions are horizontally polarized.

Welsh I.T.A. Station.—The site at St. Hilary Down, near Cardiff, Glamorgan, chosen by the I.T.A. for its South Wales and West of England station, has now been approved by the Government. Objections had been raised by air services as it was considered the 750-ft mast would constitute a danger to users of the nearby Cardiff airport.

Plastics Convention.—Seventeen papers covering the latest extrusion and injection moulding techniques and recent developments in plastics materials will be delivered during the international convention being held in conjunction with this year's British Plastics Exhibition (Olympia, London, July 10th-20th). Although none of the lectures deals directly with plastics for electronics purposes, many of the techniques and developments covered are of general interest to the industry. Admission to the exhibition costs 2s 6d, but tickets for the convention are obtainable free from *British Plastics*, Dorset House, Stamford Street, London, S.E.1.

Automatic Measuring Equipment.—A conference is being organized by the Society of Instrument Technology to provide an opportunity for the users and makers of automatic measuring equipment, and those concerned with research and development in this field, to meet and discuss their work. This conference on automatic measurement of quality in process plants will be held at University College, Swansea, from September 23rd to 26th. Further information is available from the Society at 20, Queen Anne Street, London, W.1.

The Institution of Electronics has transferred its general headquarters from London to 78, Shaw Road, Rochdale, Lancs., the address of W. Birtwistle, who is now honorary general secretary. He will continue as honorary secretary of the northern division of the Institution and as organizer of the annual electronics exhibition held in Manchester.

1,700 miles on 2 Mc/s.—The radio officer of *S.S. Spalake* reports that on a voyage from Tobruk to Malta on March 10th he maintained direct radio-telephone contact on 2.182 Mc/s with Niton Radio (GNI); a distance of approximately 1,700 miles.

Courses for overseas specialists, being organized this year by the British Council in conjunction with universities, government departments and learned societies, include one on point-to-point radio services (April 28th to May 14th) and another on digital computers (October).

Electronics Centre.—Many of the Mullard exhibits mentioned in our review of the Physical Society's Exhibition are displayed at the technical information centre recently opened at Mullard House, Torrington Place, London, W.C.1. The floor space of the showrooms and demonstration room is 5,000 square feet, and there is also a cinema seating over 70.

Careers.—A well-illustrated informative brochure "Careers in the Telecommunication Industry," has been prepared by the Telecommunication Engineering and Manufacturing Association. It has been circulated to university appointments boards, technical colleges, public and grammar schools and youth employment offices, and is also available from the office of T.E.M.A., 40-53, Norfolk Street, London, W.C.2.

A summer school on instrumentation and automatic control is being organized by the Gloucester Technical College for July 1st to 5th. A draft syllabus includes sections dealing with the basic theory of closed loop systems, servomechanisms and process control systems. Lecturers include Associate Professor E. B. Pearson (Royal Military College of Science) and Dr. G. L. d'Ombrain (Battersea Polytechnic).

"Marconi Instrumentation," the quarterly journal issued by Marconi Instruments, Ltd., which started ten years ago with an initial print order of 1,000 copies, now has a circulation of 16,000. Approximately 60% go abroad, including 3,500 to the U.S.A.

Plastics Year Book.—One of the most important features of the British Plastics Year Book, 1957, is the 142-page review of plastics patents. It contains all relevant patents issued last year, and as they are collected in subject groups, each with a potted specification, it provides a useful record of technical development in the industry. The 716-page Year Book also includes classified directories of manufacturers and proprietary names, a glossary of technical terms and a Who's Who. It is issued by our publishers and costs 2 guineas (postage 1s 9d).

FROM ABROAD

The net loss on all colour television activities of the Radio Corporation of America last year (including development, manufacture, training of technicians and provision of colour programmes) was nearly $7M. Since the introduction in 1955 of the 21-in compatible colour receiver, only 102,000 have been sold.

Canadian TV.—The 518-page report of the Royal Commission on Canadian broadcasting records that 80% of the 16M population live within the service area of one or more of the country's 38 television stations. During the past four years the number of television receivers in use has increased tenfold and now totals 2,300,000. Of the 189 sound broadcasting stations in the Dominion, 167 are privately owned.

Marine Radar Conference.—An international meeting, to be held in Genoa from May 16th to 19th in preparation for the next International Meeting on Radio Aids to Marine Navigation, will consider problems relating to the design and construction of marine radar, and the use of radar at sea. Among those contributing to the conference are Colonel J. D. Parker (secretary general, International Maritime Radio Committee) and Captain F. J. Wylie (director, Radio Advisory Service).

Television in India.—The Indian Minister for Information and Broadcasting recently announced that preliminary arrangements have been made for the country's first television station to be built at Bombay. It will probably be ready for service next year.

Novel Aerial!—A crane near the Hamburg transmitting station was found to be acting as a tuned medium-wave aerial, so that the field of the high-power transmitter was causing dangerous r.f. voltages on the grab. Using a model of the crane it was possible to evolve an inexpensive means of reducing the r.f. voltage to a safe value. This consisted in joining two points on the crane by a free hanging wire through an adjustable capacitor (about 900 pF). The main body of the crane then completed a tuned rejector circuit.

Long-Distance TV Reception.—Membership of the American "Over 50TV DX Club," as its name indicates, is limited to those who have received 50 or more television stations. The top scorer in the club, which is sponsored by our New York contemporary *Radio-Electronics*, has logged 290 stations. This total has been reached in three years and includes stations in eight countries and 45 states.

Instrumentation.—An International Congress and Exhibition of Measuring Instruments and Automation is to be held in Düsseldorf, Germany, from November 2nd to 10th.

Personalities

Air Vice-Marshal G. P. Chamberlain, C.B., O.B.E., the new deputy controller of electronics at the Ministry of Supply, has spent most of his Service career in signals. During and before the war he was with 16 and 18 Reconnaissance Groups, R.A.F., and was for some time in Australia on radar duties. His post-war service includes the directorship of Civil Air Operations at the Ministry of Civil Aviation, and after a tour of duty abroad took over the command of the R.A.F. Staff College at Andover. He is 52.

Major L. H. Peter, M.I.E.E., who, as announced last month, is the new president of the Radio and Electronic Component Manufacturers' Federation, has been with Westinghouse since the end of the first world war. In about 1926 he was made responsible for the development of metal rectifiers, and has successively held the positions of chief electrical engineer, chief engineer and, for the past ten years, chief development engineer. Major Peter was one of the six founder-members of the original Radio Component Manufacturers' Federation, and is also a member of the Radio Industry Council.

J. A. Smale, C.B.E., B.Sc., M.I.E.E., has retired from the position of engineer-in-chief of Cable and Wireless and has become technical consultant in telecommunications engineering to Marconi's W.T. Co. Mr. Smale, who is 62 and had been engineer-in-chief since 1948, was responsible for the development of long-distance c.w. relay stations as a means of overcoming unfavourable propagation conditions. He was also responsible for the design and manufacture of the first voice-frequency channelling system used commercially in this country. Mr. Smale was with Marconi's for ten years before he transferred to Cable and Wireless in 1929 where he was assistant e-in-c for 14 years.

Denis Taylor, M.Sc., Ph.D., head of the Electronics and Instrument Division at the Atomic Energy Research Establishment, Harwell, for the past 12 years, has been appointed a director and general manager of Plessey Nucleonics Limited. In addition he will become research executive of the Aircraft and Electronics Groups of the Plessey Company, and will be responsible for the co-ordination of the Company's nuclear programme. He takes up his new appointment on May 1st. Dr. Taylor, who is 46, was a member of Sir Robert Watson-Watt's team at the Bawdsey radar research station during the early part of the war, and for his "contribution to the development of radar installations" received a Government award. He later went to T.R.E., Malvern, where he became superintendent. Between 1931 and 1939 he held a number of university lectureships.

Major L. H. PETER

J. A. SMALE

E. W. Chivers, B.Sc., who for the past ten months or so has been principal superintendent of the electronics division of the Armament Research and Development Establishment (M.o.S.) at Fort Halstead, Sevenoaks, Kent, has been appointed deputy director of the establishment. He is 49. In 1947 he became superintendent of the Radar Research and Development Establishment at Malvern, and on the fusion in 1953 of R.R.D.E. and T.R.E. into the Radar Research Establishment was appointed deputy director of ground radar.

C. J. V. Lawson, M.I.E.E., the new engineer-in-chief, Cable and Wireless, was appointed deputy e-in-c only a few months ago. He was previously manager of the cable station and head of the school of telecommunication engineering at Porthcurno, near Land's End. He is 50. The new deputy e-in-c is **A. H. Harris,** who is 52. He joined the Eastern Telegraph Company in 1922 as a telegraph operator, and six years later was posted to the engineer-in-chief's department. He was transferred to C. & W. on the merger of British overseas telegraph undertakings in 1929.

Richard Arbib, this year's chairman of the R.E.C.M.F., is chairman and managing director of Multicore Solders, Ltd., which he joined some 20 years ago. He entered the radio industry in 1929 in the electrical reproducer department of H.M.V., later becoming advertising manager of that company.

Dr. DENIS TAYLOR

RICHARD ARBIB

J. M. Furnival, M.B.E., has retired from the position of general manager of Marconi Instruments, Ltd., which he has held since 1942. He will also be remembered for his pioneering work on the development of airborne radio equipment, including beam approach. He joined Marconi's W.T. Co. in 1919 for work in this field, and for some years was manager of the Company's aircraft wireless establishment at Hackbridge, Essex.

S. W. Amos, B.Sc., A.M.I.E.E., a frequent contributor to *Wireless World*, has been appointed assistant editor in the Technical Instructions Section, B.B.C. He joined the Corporation in 1941, and after two years' experience as maintenance engineer transferred to the engineering training school as an instructor. Three years later he transferred to the Technical Instructions Section where since 1950 he has been chiefly concerned with the preparation of the four-volume B.B.C. engineering text book, "Television Engineering" (issued by our publishers).

Geoffrey E. Beck, B.Sc., A.M.I.E.E., author of the article on page 225, has been with Marconi's since graduating at Birmingham University in 1938. For ten years he was in the research division, for the major part of the time working on marine radar. Since 1947 he has been in the development division where he has been concerned with suppressed aircraft aerials. Last year he was appointed group leader of airborne navigational aid development.

Inexpensive Pre-Amplifier

Simple Design for Use with Simple Pickups and Radio Tuners

By P. J. BAXANDALL, B.Sc.(Eng.)

WHILST it is generally believed that present-day crystal pickups are somewhat inferior to the best moving-coil pickups from the point of view of quality of reproduction, the best of them, when properly equalized, are actually capable of giving results which, judged aurally, do not fall far short of the best obtainable.

Crystal pickups, moreover, have the undoubted advantages of low cost and large output, and this makes them very attractive when economy must be carefully considered.

With the above thoughts in mind, it was felt that a simple pre-amplifier for use with pickups such as the Cosmocord GP20 Hi-g, or Collaro Studio Transcription, and suitable for feeding the Inexpensive High-Quality Amplifier described in the preceding two issues, might appeal to some readers. The pre-amplifier is also suitable for use with radio tuners, and its distortion is low enough to enable full justice to be done to the best f.m. transmissions.

The circuit is shown in Fig. 1, from which it will be seen that the author's negative-feedback tone control is employed[1], the first half of the double triode operating as a straightforward amplifying stage. The tone-control circuit has been slightly modified, however, compared with the version originally published, to enable a gain of approximately 3 to be obtained from this stage with the controls set for level response, instead of unity as in the original version. The price paid for the advantage of increased gain is a reduction in the available amount of treble lift, and to a lesser degree, of bass lift.

The performance of the tone control may be judged from Fig. 2, which shows the frequency response for various settings, measured between the grid of V1a in Fig. 1 and 15-ohm output terminals of the Inexpensive High-Quality Amplifier. An advantage resulting from the increased gain of the modified tone-control circuit is that the previous stage is now required to supply so small an output voltage that its distortion, even with no feedback, is only a small fraction of 1%. The tone-control stage, having negative feedback, can supply the required output of 4 V r.m.s. on sine waves with a similarly low level of distortion, so that very low total distortion is obtained in a very economical manner. To achieve this low distortion in practical use, it is, of course, imperative for the volume control to be placed before the first stage, as in Fig. 1.

The total gain, with the tone controls set for level response, is such that a sine-wave input to V1a grid of approximately 45 mV r.m.s. is required

[1] "Negative-Feedback Tone Control," by P. J. Baxandall, *Wireless World*, Oct. 1952.

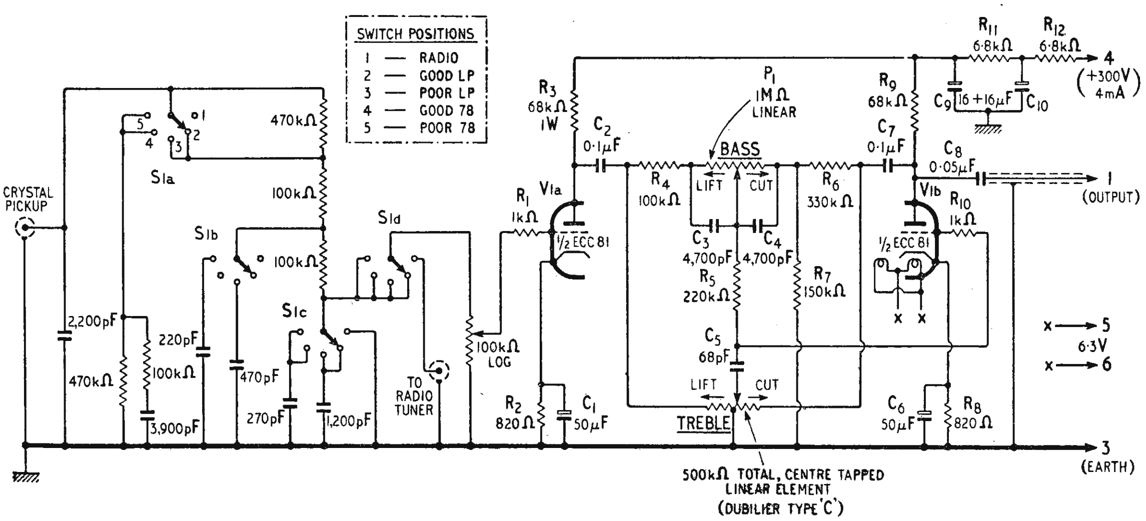


Fig. 1. Complete circuit of pre-amplifier. All resistors ½ watt ± 20%, and capacitors (other than electrolytic) ± 20%, except where otherwise specified. Mullard ECC81 may be replaced by 12AT7, Osram B309 or Services Type CV455. The numbers on the connections at the right-hand side of the circuit correspond with the numbers on the socket of the Inexpensive High-Quality Amplifier, described in previous issues. The equalizer circuit, to the left of the volume control, has been designed to suit the Cosmocord GP20 Hi-g pickup. Component values should preferably be within ± 10%.

to give an output of 5 watts from the main amplifier into a 15-ohm resistive load, i.e., an output from the pre-amplifier of 4 V r.m.s.

Due to Miller effect, the input capacitance of V1a is such that appreciable top loss will occur if the source has an effective internal resistance greater than 100 kΩ; this value gives a loss of about 1 dB at 15 kc/s.

The rest of the circuit consists of a passive network whose main function is to provide pickup equalization to suit standard recording characteristics, but it also allows additional top cut to be introduced when necessary, to improve results on worn or otherwise poor recordings. With further top cut from the tone-control, an asymptotic rate of cut of 12 dB/octave may thus be added to the equalizer characteristic if required; whilst this is less steep and the roll-off is more gradual than is obtained with filters of a more ambitious variety[2], nevertheless it will be found that poor recordings can be dealt with in quite a satisfactory manner.

The pickup equalization circuit differs from those previously published[3], and has been adopted for the following reasons:—

(a) By placing a relatively large capacitor directly in shunt with the pickup, variations in internal capacitance from one pickup sample to another, and with temperature, are prevented from having a significant effect on the equalization characteristic obtained.*

(b) Due to the presence of the capacitor across the pickup, all impedances in the equalizer may be kept reasonably low, thus reducing the effect on the response caused by stray capacitances and so making the result almost independent of variations in layout.

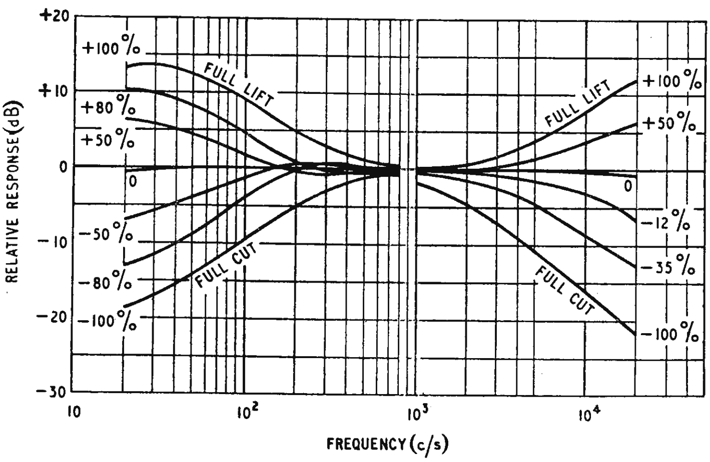
(c) The output impedance of the equalizer circuit is low enough to make it practicable, if desired, to place the equalizer and volume control in the playing desk and to connect it to the pre-amplifier via a low-capacitance screened cable up to 10 feet or so in length. By arranging matters in this way, the playing desk becomes a self-contained and fully equalized gramophone source, suitable for connection to any available amplifier capable of giving full output for a sine-wave input of 100 mV r.m.s. or less, provided the input resistance of the amplifier is not less than about 0.5/MΩ. To what extent this facility is regarded as advantageous depends, of course, on individual circumstances.

(d) The values have been so chosen that approximately the same voltage is produced across the volume control on loud 78 r.p.m. records as on loud LP records. This is not a vital point, but it is easiest for the user if about the same volume control settings are required with both types of record.

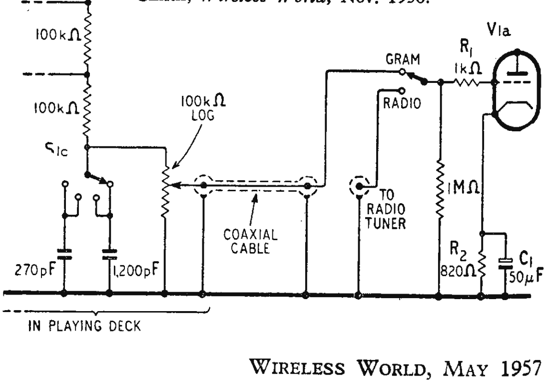
In the "Good LP" position of the equalizer switch, the equalization provided is intended to be correct for records made in accordance with the revised British Standard 1928 : 1955 LP recording characteristic[4], which is now widely adopted by recording companies. Using the author's Cosmocord HGP 39-1 LP pickup head, which is not a specially selected one, the measured response, from pickup stylus to loudspeaker terminals, with the equalizer set to the "Good LP" position and the tone-controls set

[2] "Gramophone and Microphone Pre-amplifier," by P. J. Baxandall, *Wireless World*, Jan. and Feb. 1955.
[3] "Pickup Input Circuits," by R. L. West and S. Kelly, *Wireless World*, Nov. 1950.

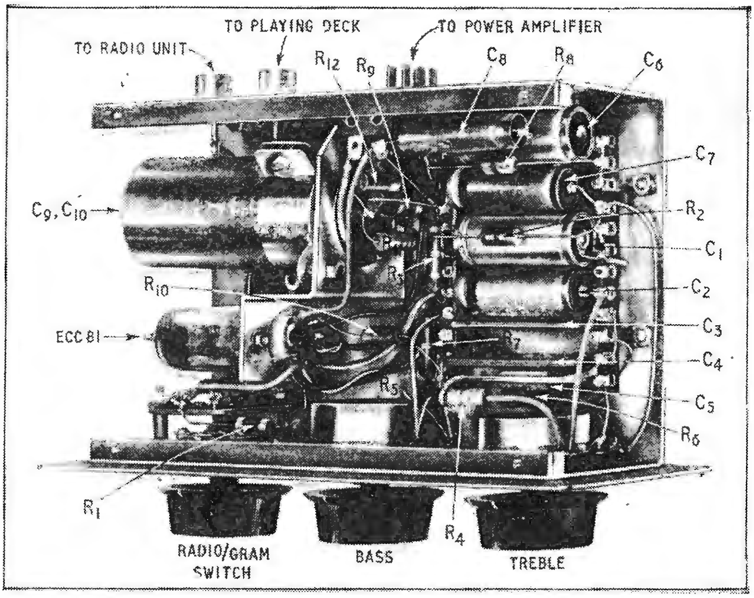
* The advantage of placing a large capacitor in shunt with a crystal pickup was first pointed out to the author by G. B. Wellgate.
[4] "Disc Recording Characteristics," by J. D. Smith, *Wireless World*, Nov. 1956.



Above: Fig. 2. Measured frequency response, between V1a, grid and output of Inexpensive High-Quality Amplifier, at various settings of the tone controls. The figures on the curves represent the percentage rotation of the knob on either side of the middle position.



Right: Fig. 3. Modified arrangement in which the gramophone equalizer and volume control are in the playing desk. The radio volume control may be fitted in the tuner unit and should have a value not greater than 100kΩ.



View of prototype pre-amplifier with dust cover removed to show layout of components.

for level response, was within ±2 dB of the intended result over the frequency range 50 c/s to 10 kc/s. (The measurements were made using the British Sound Recording Association Test Disk No. PR.301, which is recorded to the C.C.I.R. 1953 characteristic, the measured results being corrected to allow for the difference between this characteristic and the revised B.S. 1928: 1955.)

In the "Poor LP" position of the switch, an extra top cut of approximately 6 dB at 10 kc/s is introduced.

In the "Good 78" position of the switch, the equalization is suitable for a recording characteristic having 6 dB/octave asymptotes with corner frequencies at 250 c/s (bass cut) and 6 kc/s (top lift). This is considered to be a good compromise, and with judicious use of the tone controls when necessary, any normal 78 r.p.m. record can be well reproduced.

In the "Poor 78" position of the switch, an extra top cut of approximately 6 dB at 10 kc/s is introduced.

In the "Radio" position of the switch, a sine-wave input of about 45 mV r.m.s. is required for full output. Many radio tuners will give a larger output than this, and are designed to feed into a higher resistance load than 100 kΩ; in such cases a suitable resistor (e.g., 470 kΩ) should be connected in series with the "Radio Input" socket.

If the equalizer circuit and gramophone volume control are put in the playing desk, a simple change-over switch, with positions labelled "Radio" and "Gram" will be required in the pre-amplifier, and the radio volume control may be fitted in the radio tuner unit. The unit photographed is intended for use in this way, the connections being shown in Fig. 3.

Fig. 4 shows an equalizer circuit performing the same functions as that included in Fig. 1, but designed to suit the Collaro Studio Transcription pickup, which responds fairly smoothly up to 15 kc/s under both LP and 78 conditions. The equalization provided is also reasonably accurate for the Collaro Studio P pickup.

In the "Poor 78" position of the switch, it will be seen that two additional top-cutting capacitors are introduced, giving an extra attenuation of about 10 db at 10 kc/s. By omitting the 150-pF capacitor, the attenuation is reduced to about 6 db, which is the same as for the GP20 Hi-g equalizer circuit; in general, however, it is considered to be advantageous to include this capacitor, as it gives an appreciable reduction in scratch, etc., on bad records.

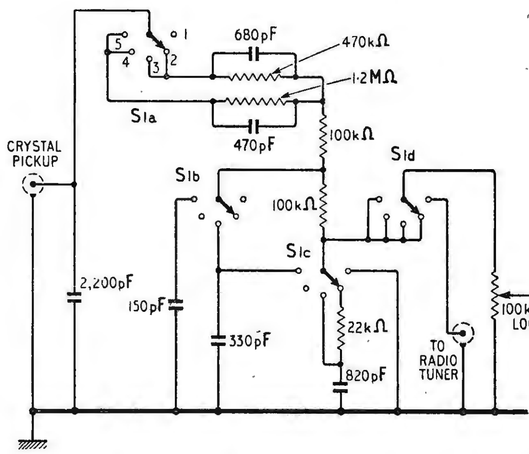


Fig. 4. Equalizer circuit designed to suit the Collaro Studio Transcription pickup. Component values should preferably be within ± 10%.

It may be worth mentioning that it appears to be a characteristic of present-day crystal pickups that the variations in frequency response and sensitivity between one sample and another of nominally the same model are rather greater than for some other types of pickup. Consequently the equalization circuits given may not be quite optimum for any particular sample of pickup, but the departure from ideal equalization is unlikely to be very noticeable audibly. In the unlikely event of insufficient amplifier gain being available for full volume with a low-sensitivity sample of pickup, the value of the capacitor connected across the pickup may be reduced a little; the accompanying slight loss of bass may be compensated by using the bass tone control.

Construction.—Various layouts are, of course, practicable for a circuit such as this, and the choice may be left to the reader. The most economical arrangement would be to build the pre-amplifier, with or without equalizer, on the same chassis, suitably enlarged, as the main amplifier. Whatever is done, the following points should be watched:—

(a) The components associated with V1a grid circuit should be well separated from signal-carrying wiring in later parts of the circuit, otherwise the top response may be modified due to unintentional feedback via stray capacitances. Similarly the anode circuit wiring of V1b, i.e., that associated with R_6, C_7, R_9 and C_8, including the output lead and the lead to P_2, should be kept well separated from the grid circuit components (R_5, C_5 and R_{10}) and their wiring.

(b) An ordinary black Bakelite valveholder should not be used if the lowest hum level is desired, but rather one of the light brown (nylon loaded plastic) variety; this will give less leakage current between heater and grid pins. A p.t.f.e. valveholder is an unnecesary extravagance at the signal level involved in this pre-amplifier. A further point is that the heater wiring should be twisted and kept as clear of the signal wiring as practicable.

(c) In the prototype unit, the valve and the 16+16μF capacitor have been mounted on a small sub-assembly resiliently attached to the main chassis using screws passing through soft rubber grommets. This reduces the risk that microphony in the valve may cause a howl to build up when the pre-amplifier is used close to a loudspeaker. Whilst it is probable that this precaution would normally be found quite unnecessary, it is nevertheless easy to take and at least can do no harm. Do not forget, however, to make an earth connection between the sub-assembly and the main chassis, otherwise, as the author discovered to his cost, there will be no h.t. decoupling and "motor-boating" will ensue!

(d) If the equalizer and volume control are incorporated in the playing desk, it is essential for them to be completely screened electrostatically. An ordinary tin box is perfectly satisfactory.

Testing.—After completion, it is desirable at least to check that the d.c. operating conditions in the two stages are reasonable. The cathodes should nominally (with 300—V h.t.) be at +1.6 V and the anodes at +115 V. Provided the measured values are within the limits 1.3 to 1.9 V and 80 to 150 V, and provided none of the readings is affected by operating the tone-control knobs, all may be assumed to be well in this respect.

The hum level, at the output of the Inexpensive High-Quality Amplifier, should be hardly any greater with the pre-amplifier connected than it is with the input to the main amplifier short-circuited; it should be only just audible with one's ear close to the loudspeaker in a very quiet room.

In the absence of facilities for frequency-response measurements, listening tests should be used to find out whether the controls are producing their intended effects. Turning the potentiometer knobs should not itself produce any noises from the loudspeaker, when no signal is applied.

Quantum Amplifiers

THESE amplifiers, with their attractive possibility of very low noise, are arousing increasing interest. They depend on the creation of a non-equilibrium distribution of energy between quantum states in atoms or molecules. Energy at the frequency of transition to the equilibrium state can be extracted by stimulation with an applied signal at the same frequency in the form of coherent radiation or of noise. According to the available energy, amplification or oscillation is possible.

What was apparently the first such amplifier was discussed by J. P. Gordon *et al.* in the *Physical Review* of August 15th, 1955. This uses an ammonia beam with electrostatically separated molecular energy states. The beam density must be small to prevent rapid spontaneous transition back to the equilibrium state. This severely limits the available energy to only about 5×10^{-10} watts. The authors coined the name "maser" (standing for "microwave amplification by stimulated emission of radiation") for such quantum amplifiers.

More attractive possibilities (discussed in a letter from M. W. P. Strandberg in the *Proc.I.R.E.* for January, 1957 and by Prof. N. Bloembergen in the *Physical Review* of Oct. 15th, 1956) are offered by proton or electron spin states in solids. The spin may be thought of as producing a magnetic moment that can align itself with or against an applied magnetic field, thus producing two possible states. Non-equilibrium spin states can be prepared in several ways, the simplest being the application of a pulse of coherent radiation of the correct frequency cut off at a suitable phase. Spin densities much higher than those in ammonia beams are obtainable, and can be effectively increased still further by rapid cycling from the equilibrium to non-equilibrium states (e.g., at a typical radar p.r.f. of 10^3 c/s per sec.). Much slower spontaneous transition back to the equilibrium state (longer relaxation time) than in the ammonia beam can also be realized both for certain nuclear proton spin states and certain paramagnetic electron spin states. This gives a longer time for experiments on the non-equilibrium state, and moreover, the power requirements to produce saturation of this state are reduced. The transition frequency is proportional to the magnetic field, so that variation of this field offers wide-range tuning possibilities. By contrast the ammonia transition frequency that is used is fixed within a few Mc/s of its centre value (about 24 kMc/s).

A solid state "maser" using electron spins has recently been produced at the American Bell Laboratories by Dr. D. Scovil *et al.* It oscillates at X-band (9000 Mc/s) with a power of about 2×10^{-6} watts. Another experiment carried out in France (described by Combrisson *et al.* in *Compt.Rend.Acad.Sci.* of May 14, 1956) also used electron spins and a similar operating frequency. Insufficient power was available to produce oscillations, but some amplification was observed.

These quantum states are largely independent of thermal motion so that their noise can be equivalent to that at a very low effective temperature, only a few degrees above absolute zero. Noise is thus 20 to 30 dB down on that in normal receivers; and theoretical calculations indicate that sufficient gain can be realized to take advantage of this low noise figure. The consequent possibility that transmitter power could be reduced in this proportion (20 to 30 dB) without any decrease in effectiveness would revolutionize microwave technology. The equal possible increase in receiver sensitivity would be of tremendous value in the field of radio astronomy.

This low noise is also equivalent to operation with a very high Q-factor. For example, two of the original "masers" have been used to produce beats at 30 c/s with no apparent random phase variations. This indicates a stability to within a tenth of a cycle in 24 kMc/s!

Physical Society's Exhibition

NEW ELECTRONIC DEVICES AND TECHNIQUES

Valves and allied devices shown at this exhibition will be described in the June **Wireless World**, *while new test and measuring gear will be reported in the July issue.*

THE dividing lines between pure and applied research and between research and development become increasingly difficult to draw in these days of intense activity in the physical sciences. In the Physical Society's catalogue there used to be a separate section for the research exhibits; now they are inextricably dispersed among the experimental, prototype and finished products of industry.

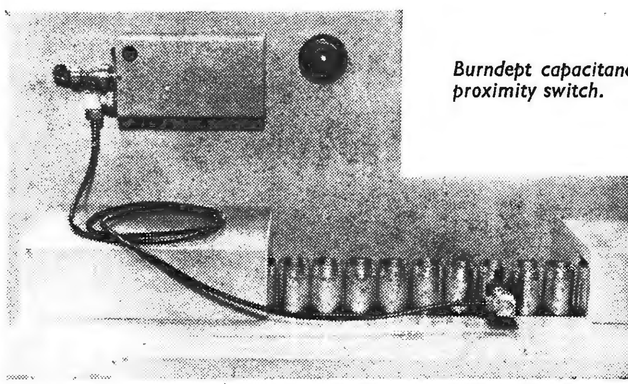
Applications of newly discovered physical effects are often thought of before the fundamental process has been fully explored, and research and development proceed on parallel lines. **Nuclear resonance**, for example, is already being used as a means of measuring magnetic flux, and in a portable fluxmeter shown by the Admiralty Signal and Radar Establishment is used to calibrate and stabilize the field of an electromagnet supplied from a 50c/s source. A regenerative receiver supplies a r.f. field at right angles to the magnetic flux and indicates precessional resonance of the proton nucleus of the hydrogen in water surrounding a search coil. There is a change in Q of the coil at resonance which is displayed as a pulse on an oscillograph trace. Changes in the magnetic field due to instability can be reduced by a factor of 60 by feeding back the pulses to the magnet power supply.

Frequency Standards.—A resonant transition between two energy states in atoms of the element cæsium in which the magnetic moment of the atom is reversed has been used by research workers at M.I.T. as a frequency standard of high accuracy (9192.63185 Mc/s) which is unaffected by external fields. By locking an oscillator to this frequency through a discriminator circuit it is possible to establish a time standard with a stability of 1 part in 10^9. The Royal Aircraft Establishment showed a light portable version of the original M.I.T. apparatus which had been constructed by Standard Telephones on a study contract for the Ministry of Supply.

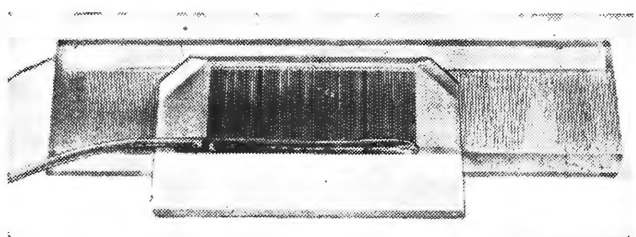
Research and development are nowhere more closely associated than in the improvement and exploitation of special materials. Photoconductive cells, for the detection of infra-red radiation, consisting of single crystals of indium antimonide, were shown by the Radar Research Establishment, while the Research Laboratories of the G.E.C. exhibited single-crystal cells of cadmium sulphide for the wavelengths of visible light in which variations in spectral sensitivity can be induced by various activation techniques. Large powder-layer cells of this material with a peak response in the spectrum of tungsten filament light were shown which if required can be designed to pass currents up to 1 ampere for the direct operation of relays.

Length and Displacement.—Applications of electronic methods to the control of industrial processes, although sometimes complex, are essentially elaborations of simple basic principles. The measurement of length or displacement, for instance, can often be made in terms of capacitance, or by change of inductance when movement is imparted to the core of a coil. In the "Magna-Gage" shown by Southern Instruments a differential inductance transducer actuated by a probe is used as a sensitive feeler gauge; a 10-kc/s output from the transducer is amplified, rectified and applied to a centre-zero meter with a calibrated range of ± 0.0005 in. The change of capacitance of a probe electrode is utilized in the Burndept proximity switch to detect the passage of opaque objects (e.g., metal cans) on a conveyor belt which, if touching, cannot be registered by conventional photoelectric counters.

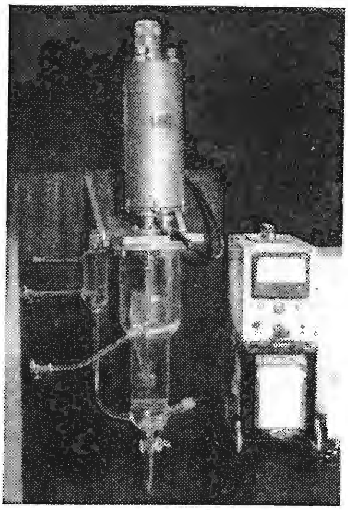
For the accurate determination of position over a wide range, as in machine work tables, a form of linear resolver has been developed by Plessey in which the equivalent of the rotor and stator windings of



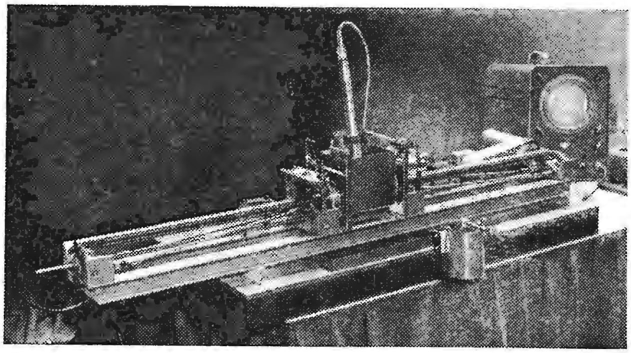
Burndept capacitance proximity switch.



Plessey Linear Inductosyn scale and slider for automatic machine tool control.



Pye liquid density indicator.



Ultrasonoscope automatic scanner for inspection of metal bars.

a rotary resolver are printed flat on superimposed slides. The pole spacing represents 0.1in and by interpolation settings to 0.0001 in can be repeated with an accuracy of 25 microinches. A somewhat similar principle is employed in a control rod position indicator demonstrated by the U.K. Atomic Energy Authority. Transducer coils spaced three to each interval of length (pitch) are influenced by steel collars attached to the rod. The output from one fixed coil is 120° out of phase with its neighbour and when each group is connected to the three stator windings of a synchro, 360° rotation is provided for each pitch (0.6 in). Settings are accurate to 0.02in in 25 inches.

Fluid Density.—The density of fluids is measured in terms of displacement in an instrument by Pye which uses an inductive transducer to register the height of a hydrometer float. Temperature compensation can be applied electrically when the concentration of saline solutions is to be controlled.

Absorption of gamma rays is the principle underlying the Ekco fluid density gauge. It can be used for liquids flowing in pipes of any material and will detect changes of density of 0.005.

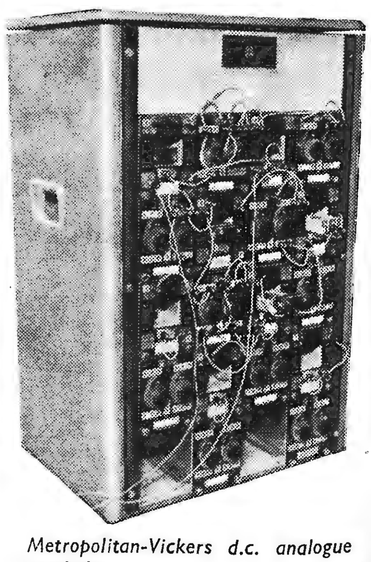
Liquid Level. — Conventional methods cannot be employed when radioactive solutions are involved, and the problem has been solved by the Industrial Group, U.K. Atomic Energy Authority, by taking advantage of the change in low-frequency inductance of a coaxial line, consisting of a perforated stainless steel tube with centre rod, when the level at which it is short-circuited is altered by the height of the conducting solution.

Magnetostrictive and Piezoelectric Transducers for the generation of ultrasonic vibration exploit the properties of a variety of materials from nickel to ceramics, and there was evidence of wider use of the latter class in many applications. Plessey, for example, have developed an ultrasonic abrasive drill using a cylindrical element of barium titanate. Increased efficiency of energy conversion is claimed for lead titanate/lead zirconate ceramics which are under development by Radio Heaters, Ltd. These materials also have higher thermal stability and can be worked with higher power loadings per cm^2 than barium titanate.

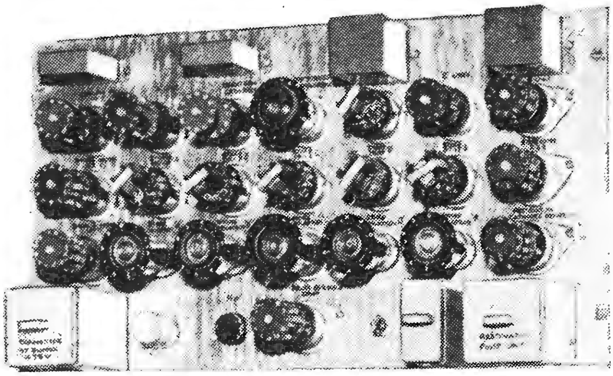
Ultrasonic testing of materials for flaws has been established for some time, and many portable instruments using manually operated test probes are available. A special installation for the continuous testing of metal bars was shown by Ultrasonoscope. The bar is immersed in a tank of liquid and scanned tangentially by a beam from a transducer which need not be in contact with the surface of the test piece. The dimensions of the tank and the spacing between transducer and specimen are chosen to place irrelevant return echoes outside the range of the oscilloscope time scale.

"Bender" elements consisting of ceramic strips backed by metal are used in relays developed by G.E.C. Research. They have the great advantage that, unlike magnetic relays, negligible power is required to hold the contacts closed.

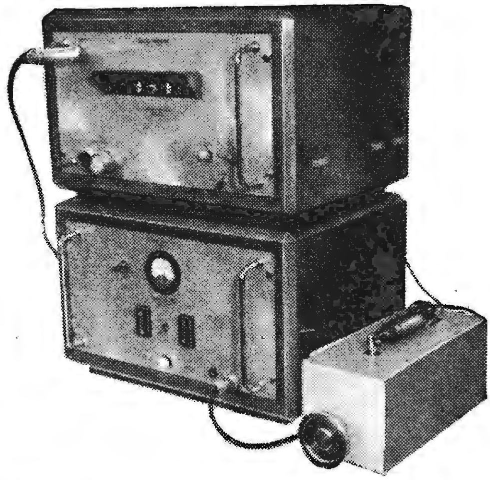
Analogue/Digital Converters are used in measurement and control systems where the voltage output of a transducer, measuring some physical variable, has to be converted into digital form for numerical indication or feeding into digital data processing equipment. Many work on electromechanical principles, the usual method being to apply the analogue voltage to a self-balancing bridge incorporating a servo motor. The rotation of the motor in balancing the bridge drives a commutator system, and the brushes on this give digital signals representing the angular displacement and hence the amount of bridge unbalance caused by the applied voltage. An instrument in this category shown by J. Langham Thompson uses a uniselector as a combined servo motor and commutator. A purely electronic method well represented at the Exhibition was the so-called "subtractive comparison method," usually giving the result in binary notation. Here the input voltage is repeatedly compared with fixed reference voltages representing digits of the final answer. When the first reference is subtracted from the input, if the



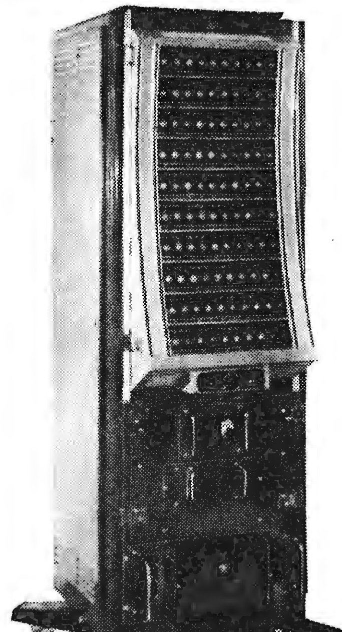
Metropolitan-Vickers d.c. analogue computer.



Siemens-Ediswan transistor-driven Dekatron counter.



J. Langham Thompson digital indicator with strain gauge on the right.



Philips pulse height analyser.

residue is positive a "1" digit is indicated and if it is negative a "0" is shown. The residue is then passed to the next digit stage, where the same process is performed, and so on. Elliott, Mullard and Southern Instruments all had converters of this kind, the Mullard device using transistor circuits and giving 8-digit binary indication.

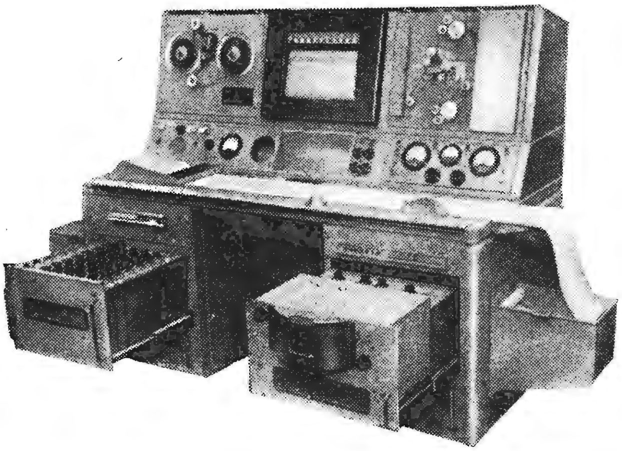
Digital Indicators were very much in evidence, especially in association with the above-mentioned converters. The Langham Thompson equipment, for example, uses a new type of glow discharge tube for decimal numbers in which the numerals are formed by shaped wire electrodes placed one in front of the other. Each numeral lights up when an appropriate trigger voltage is applied to it. Other instruments used a new indicator made by Hilger and Watts. In this, each numeral is engraved on a Perspex plate, and the plates are stacked and illuminated from the edges by small lamps.

Analogue Computers on show this year included a new d.c. equipment made by Metropolitan-Vickers and notable for its compactness. Designed on the unit principle, the drift-corrected d.c. amplifiers are balanced and give two outputs of opposite sign, thereby reducing the number of amplifiers required for certain calculations. The machine is suitable for solving differential equations and studying servo-mechanisms by simulation. Elliott have further extended the range of possibilities of their well-known G-PAC d.c. machine with various new accessories including a function generator and an electro-mechanical servo multiplier.

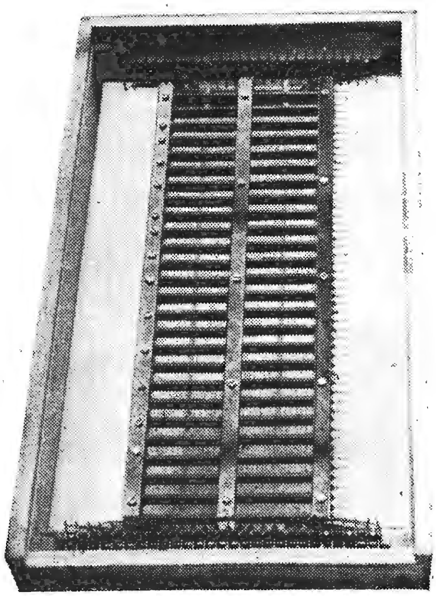
Transistor Computing Circuits for digital work are becoming more prominent now that r.f. transistors with 5-10-Mc/s cut-offs are allowing faster pulse rise times. Metropolitan-Vickers were not showing their new "950" transistor computer, but Ferranti had some interesting plug-in transistor logical circuits performing simple operations at the high digit rate of 1 Mc/s. These do not employ conventional Boolean logic, but a so-called "ballot-box logic," using small transformers with various input windings as the combining elements—the transistors merely acting as pulse amplifiers. The units are standardized and interchangeable and can readily be connected as adders, subtractors, etc. Mullard were showing logical circuits using both transistors and magnetic cores, the last-mentioned acting as two-state storage elements and the transistors as driving amplifiers. Usually, this type of circuit is limited by the magnetic cores to operation up to about 100 kc/s.

Pulse Counters of all kinds were to be seen in great profusion, mostly based on well-known techniques. There were, however, a few rather unusual examples. Siemens-Ediswan had an equipment in which Dekatron tubes were driven by pulses derived from transistor blocking-oscillator circuits—the h.t. for the Dekatrons being derived from a transistor "chopper" power supply so that the whole unit could run from only 20 volts. Mullard had a new transistor counter using r.f. junction types to permit working at the high p.r.f. of 1 Mc/s. A Dekatron counter designed for automatically printing out its figures on a roll of paper was displayed by Labgear, while another shown by Ericsson had a bi-directional facility—the glow discharge being moved either forwards or backwards according to the direction of rotation of a disc from which the pulses were generated by an optical commutator.

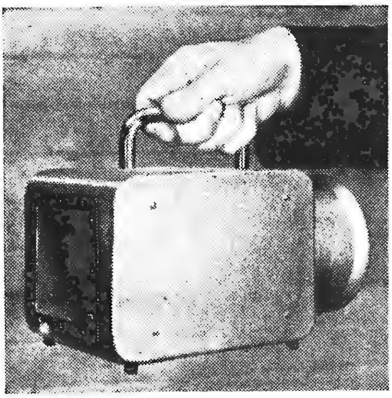
Pulse Height Analysers are actually counters arranged to display the counts occurring at different pulse amplitudes. They are often used in conjunction with radiation detectors for examining radioactive materials, the pulse counts being plotted on a graph against amplitude levels. In the single-channel type, as shown by Isotope Developments, the gating of the pulses into the various amplitude levels is done by a bias control, which



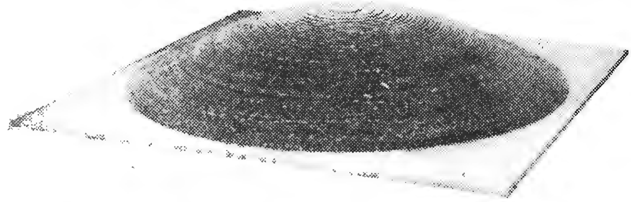
Mervyn Instruments frequency/amplitude analyser for transducer signals, with magnetic-tape playback.



Right: Standard Telephones magnetic-cell storage system.



Redesigned 3-cm microwave course beacon receiver made by Elliott.



Polystyrene-copper artificial dielectric microwave lens (Admiralty Signal and Radar Establishment).

is automatically moved slowly through the required range in synchronism with a pen-recorder chart. The number of counts obtained at each level is then indicated by the pen deflection at the corresponding position on the chart. In the multi-channel equipment demonstrated by Philips, however, there is a separate counter for each amplitude level (99 in all). Each incoming pulse is arranged to charge a storage capacitor to its peak value. The capacitor is then discharged in a series of accurately controlled steps, and the number of steps (which of course indicates the pulse amplitude) is used to work an electronic rotary switch which gates a count of one to the appropriate counter. The electronic rotary switch, incidentally, uses the new "trochotron" high-speed beam switching tube developed by Ericsson in Sweden.

Magnetic Matrix Stores, using tiny ferrite cores with rectangular hysteresis loops, are now being produced as complete units on a commercial basis by both Mullard and Plessey. In addition there were several experimental arrangements on view. Mullard, for example, showed how the magnetic cores could be switched directly by transistors —actually experimental high-frequency power types giving 2-μsec pulses of 350-mA amplitude at a p.r.f. of 100 kc/s. The magnetic-cell version, however (using holes drilled in a block of ferrite), is more suitable for transistor drive because of the lower switching current required. S.T.C. demonstrated an example of this as part of an error-indicating telegraph system. The output signals were also amplified by transistors and fed into a simple transistorized logical circuit.

Ferroresonant Two-State Devices using ferrite-cored inductors were demonstrated by Mullard. In these the inductor is switched by a trigger winding from a high-current, low-inductance state, at which it resonates with a capacitor, to a low-current, high-inductance state, at which no resonance occurs (see our July, 1956, issue). Apart from their reliability and robustness, these devices have the advantage over most other magnetic two-state elements that the stored information can be read out without erasing it at the same time.

Microwave Equipment.—It may be unusual to use a waveguide as a cable in a communications system; nevertheless Elliott employ one of circular section in a microwave telephone link they have developed. It operates on 8.5 mm using the H_{01} mode of transmission and is said to have the very low attentuation of 2 dB per mile and be capable of carrying many hundreds of speech and television channels.

Elliott were also showing a redesigned version of their 3-cm microwave course beacon for guiding ships into harbour. The receiver now employs six transistor stages, gives an overall gain of 82 dB and is entirely self-contained with $4\frac{1}{2}$ V battery, loudspeaker and receiving horn.

A further development in the construction of microwave dielectric

(Continued on page 217)

lenses was shown by the Admiralty Signal and Radar Establishment. This lens is made up from layers of a "mosaic" of small copper discs on polystyrene film separated by honey-comb grids of polystyrene. Transmission losses are given at 0.5 dB per 100 layers at X-Band frequencies and the bandwidth is extremely wide. The density of the composite material is only one-fifth that of the natural dielectric.

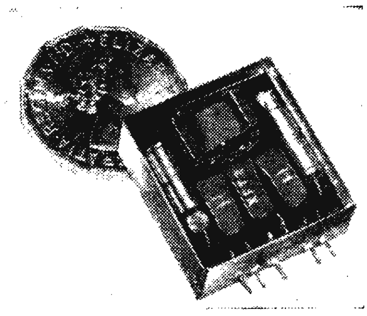
According to Mullard, a reasonably cheap way of constructing intricate sections of waveguide is to use a plastic form, give it a 40-thou. coating of silver, dissolve out the plastic and, after adding flanges and other items, fix it to a steel supporting yoke. Other examples of waveguide components were shown by Hilger and Watts and by Sanders Electronics; the latter firm had some improved versions of their "inexpensive" X- and J-Band (8 to 12 and 12 to 18 kMc/s repectively) waveguide test benches.

Materials with a high absorption characteristic over the range 2.5 kMc/s to 50 kMc/s are being produced by Plessey mainly for microwave "darkroom" applications. Grade AF10 and Grade AF11 are a kind of foam rubber made in 1-ft squares with one surface of cellular formation. The cells provide a graded transition from the impedance of free space to that of the highly attenuating material, and over the 10- to 50-kMc/s band absorption is of the order of 99.7%. A loaded rubber material, Grade M, is also available for shielding radomes when bench-testing radar scanners.

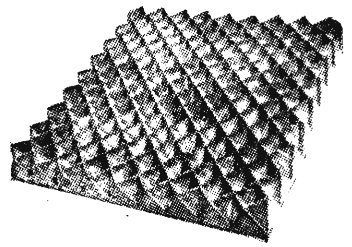
Transistor Components.—Further miniaturization of transistor components was the key-note of Fortiphone's exhibit this year. Encapsulation in epoxy resin is used extensively and, as an example of what can be achieved in this way, there was an encapsulated three-stage transistor a.f. amplifier which would lie on a penny without overhanging the rim of the coin. A new "Z" series of transformers measures only 0.575 × 0.25 × 0.25 in overall and production has been made possible by a new technique in winding fine wires, such as No. 52 s.w.g.

Extension of the Plessey series of tantalum electrolytic capacitors now brings six different sizes into the transistor category. These range in size from a button type, no larger than a sixpence, to a tubular style of 0.08 in diameter and 0.1 in long. Capacitance range is from 0.25 to 750 μF and from 3 V working to 70 V with numerous intermediate values and working voltages.

Miscellaneous Equipment.—Two items of equipment not fitting into any particular category in this exhibition was a Radyne 1-kW induction heater, for "firing" the getter in thermionic valves and heating the electrodes during the "pumping" process. A u.h.f. mobile radio-telephone for use in the 450- to 480-Mc/s band, made by Elliott, operates on a single crystal-controlled frequency. The transmitter output is between 10 and 20 watts, according to the radiated frequency, and the receiver is a double super-hetrodyne.



Sub-miniature three-stage transistor a.f. amplifier (Fortiphone).



Plessey microwave absorbing material, Grade AF11.

COMMERCIAL LITERATURE

Electronically Changed Transformer Taps to reduce the effect of mains voltage variations are discussed in a leaflet from Claude Lyons, Ware Road, Hoddesdon. Input changes of up to −20% or +10% from the nominal value are reduced to within ±5% of this value. The waveform is not distorted, and control is unaffected by frequency variations from 45 to 65 c/s. Alternative ratings of 2½ and 5 amps are available, and the power consumption is only 15 watts.

Quartz Crystals and Temperature Controlled Ovens in many different ranges are the subject of a leaflet from Bulova Watch Co., 62-10, Woodside Avenue, New York. Individual frequencies range from 16 kc/s to 100 Mc/s and include standard crystals from 140 kc/s to 250 kc/s. Two of the six ovens permit control to within ½°C.

Two Transistorized p.a. Amplifiers giving 10 or 15 watts output at 15 ohms impedance for 5 mV low impedance input are described in a leaflet from Lustraphone, St. Georges Works, Regents Park Road, London, N.W.1. Power consumption for either amplifier ranges from about 2½ watts (quiescent) to 20 watts (peak). The size is 5⅜in × 3⅝in × 3⅞in and the weight 3½lb. New microphones are described in another leaflet from the same company. These include a tubular hand microphone for close-talking in high ambient noise.

Kit-Model Oscilloscope and Valve Voltmeter are described, with very full constructional details, in two brochures from Cossor Instruments, Highbury Grove, London, N.5. The oscilloscope Γ-amplifier sensitivity is variable up to 50 mV/cm with a frequency response 3 dB down at 5 c/s and 3 Mc/s. A calibrating voltage at 50 c/s is available. The valve voltmeter has full-scale ranges from 1.5 to 1,500 volts d.c. or a.c. As an electronic ohmmeter it measures 0.1Ω to 1,000 MΩ with internal battery. On ranges up to 150 volts the frequency response is from 40 c/s to 1 Mc/s within ±10%.

Plugs and Sockets of the miniature "Jones" type. A new range under the name "Multicon" incorporating many improved features is described in a comprehensive illustrated catalogue from Painton and Co., Kingsthorpe, Northampton.

Nickel Plating for engineers. A useful illustrated booklet of 72 pages, including surface preparation, commonly used solutions, plating procedures, plant required and mechanical properties of deposits and methods of testing them. From The Mond Nickel Company, Thames House, Millbank, London, S.W.1.

Marine Radiotelephones, suitable for small craft, incorporating direction finders and Consol meters. Transmitter: 17 watts output, crystal controlled on any eight channels between 1.6 and 6Mc/s. Receiver: sensitivity 8μV for 20dB signal/noise; d.f. facilities on all wavebands 150kc/s-3.8Mc/s. Equipment operates from 12V or 24V batteries. Details on leaflets from Woodson's Marine Radio Manufacturers, Greenbank Road, Aberdeen.

Rectilinear Galvanometer Recorder, with two independent galvanometers and inking systems for side-by-side recording of two variables on a common time base. Sensitivity: 0.45in/100μA. Pen speed: 0.25sec/f.s.d. Ten chart speeds are available. Folder from Texas Instruments, 3609 Buffalo Speedway, Houston, Texas, U.S.A.

Potting Service, for development and production of resin-encapsulated electronic circuits and components, is outlined in an illustrated brochure from Lion Electronic Developments, Lion Works, Hanworth Trading Estate, Feltham, Middlesex.

Time Constants

By "CATHODE RAY"

ESPECIALLY OF INDUCTIVE CIRCUITS

TO tell the truth, this was to have been "Blocking Oscillators." The general idea was that a blocking oscillator circuit, which looks one of the simplest oscillator circuits known, is made up of still simpler combinations of resistance and capacitance or resistance and inductance, whose principles are very familiar. By first quickly reviewing these principles, the explanation of the complete blocking oscillator circuit was to have been rendered foolproof (if you will pardon the implied insult).

In spite of the fact that the more knowledgeable the authority the worse the reputation he gives the blocking oscillator for obscurity, this is still roughly my plan. Where it came unstuck in detail was that some of the principles of simple combinations of resistance and inductance turned out to be considerably less familiar—to me, anyway—than I had supposed. So much so that I have had to abandon the quick preliminary review idea and expand it into a full topic, postponing the blocking oscillator until next time.

You will have noticed that I still reckon the behaviour of combinations of resistance with capacitance as familiar. But in case I am wrong about this—and for the sake of comparison with the inductive counterparts—I am going to review it all the same. There are various ways of doing it, but for the purpose in mind I think it will be best to look at the arrangement shown in Fig. 1.

Here C is supposed to start uncharged, at $v_C = 0$. Unlike resistance, across which a voltage can jump instantly from one value to another, the voltage across a capacitance can only change gradually, as a result of a transfer of energy to its electric field, caused by the flow of current into it for a period of time. So immediately the circuit has been closed by moving the switch to A, v_C is still nil. The whole of V is therefore free to drive current through R_1 and the amount of this current can be calculated by what is commonly though not very correctly referred to as Ohm's law—$i = V/R_1$. This current starts to charge C, so v_C begins to build up.

Capacitance has its own "Ohm's law," namely, that the voltage across it due to Q amp-seconds that have flowed into it is Q/C. If our charging current

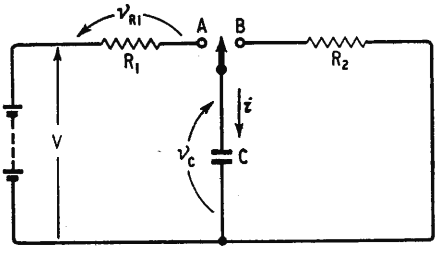


Fig. 1. The first experiment: C is charged by switching to A and then discharged by switching to B.

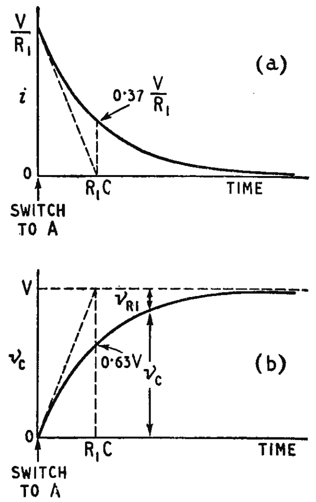


Fig. 2. Time curves of (a) current into and (b) voltage across C in Fig. 1 from the moment of switching to A. After a period equal to R_1C (the "time constant") the charging process would have been completed if the starting rate had been kept up.

V/R_1, continued steadily for t seconds, C would thus be charged to

$$\frac{V/R_1 \times t}{C} \text{ volts}$$

So we can calculate the particular time T which would have to elapse for C to be charged up to the full applied voltage V:

$$\frac{VT}{R_1C} = V$$

$$\therefore T = R_1C$$

This time T, sufficient for a capacitance to charge fully to any voltage applied through a resistance, if the starting current were maintained, is what is called the time constant; as we see, it is equal to the capacitance multiplied by the resistance, in ohm-farads or megohm-microfarads to give seconds.

Obviously the starting current is not maintained, for directly v_C begins to grow there is that much less of V to drive current through R_1. When C is half charged, only half V is available, so the current and hence the rate at which v_C grows is half what it was at the start. The graph of the current i thus has the peculiarity that the steepness of its slope at any point is proportional to its height at that point, as in Fig. 2(a). The name for this peculiarity is *exponential*. Its mathematical equation (but don't bother about it if you don't want to, for we shall not be using it) in this case is

$$i = \frac{V}{R_1}e^{-t/R_1C}$$

where e is the base of natural logarithms (2.718...etc.).

According to the late Dr. Ohm, the voltage across a constant resistance is directly proportional to the current through it. Consequently the i curve, Fig. 2(a), will do also (to an appropriate scale) as a curve of v_{R1}, the voltage across R_1. This is economy of effort.

The advantage of having a curve of v_{R1} is that because v_{R1} and v_C everywhere add up to the constant voltage V, which is equal to the starting value of v_{R1}, a curve of v_C (Fig. 2(b)) can be obtained by the simple operation of turning the v_{R1} curve upside-down. This is another economy of effort. The v_C curve helps one to visualize the charging process, for it shows how V is shared from moment to moment between C and R_1: at first, entirely across R_1; then increasingly—but at a reducing rate—across C.

In both parts of Fig. 2 the starting slope of the curve is shown continued as a dotted line, to indicate the time constant, R_1C seconds. It turns out that in that time the curve has always gone just over 63% of the way towards its destination, leaving nearly 37% to go. In twice the time (2 R_1C) the v_C curve has $0.37^2V = 0.135V$ left to go; in $3R_1C$, $0.37^3V = 0.05V$; and so on.

The gap never completely closes, but when it has become negligible we flip the switch over to B. The voltage applied through R_2 is zero, so v_C (starting practically equal to V) changes via another exponential curve towards that value, as we see in Fig. 3(b). For the fun of it I have made R_2 greater than R_1, so the time constant is greater, and more time is taken to go the statutory 63% of the way from starting to finishing voltage. Nevertheless, this die-away or discharge has the same shape as the build-up, differing only in horizontal scale and in being upside-down.

The discharge current, too, has the same shape as the charge, but because the current is in the opposite direction it must be reckoned negative (Fig. 3(a)). And besides the change of horizontal scale there is a change of vertical scale, for the higher resistance means less current.

So much for capacitance and the building up and releasing of its electric field. When we considered duality* I mentioned that the great advantage of the idea was that it gave two sets of information for the price of one. (More economy of effort.) Having taken the trouble to work out what happens in circuits combining resistance and capacitance, say, one doesn't have to think it all out again for resistance and inductance. Inductance being the "dual" of capacitance, one can use the same formulæ, curves, etc., after having made the necessary exchanges with the other duals involved; e.g., current for voltage, and series for parallel.

This being so, there might seem to be little excuse for the principles of RL circuits being less familiar than the RC principles just reviewed. Actually, however, there are several excuses, not counting the one that lots of people still don't know about this new-fangled duality (actually, like most things, quite old). For instance, a strict dual of the circuit in Fig. 1 is not really practicable. In Fig. 1 there is no great difficulty in switching the charged C from A to B without anything much happening to it *en route*. But to transfer its dual—an inductor magnetized by current—intact from one circuit to another it is necessary to short-circuit it in such a way that the total resistance is zero. But whereas it is possible in practice to have a good approximation to a capacitance with no shunt conductance, one can only get a good approximation to an inductance with no series resistance by reducing its temperature to nearly 273°C below zero, which is inconvenient.

Yet another complication is mutual inductance, which has no counterpart on the capacitive side.

Still, we shall be able to trace an analogy with at least the first part of the Fig. 1 experiment if we adopt the arrangement shown in Fig. 4. With C we started from the fact that the voltage across it cannot be changed instantaneously; it is a measure of its electric field and has to be built up by current flowing in for a period of time. With L, the current through it cannot be changed instantaneously; it is a measure of its magnetic field, and has to be built up by applying an e.m.f. for a period of time. So immediately the switch in Fig. 4 has been closed there is no current through L. Consequently there is no current through R_1, so no voltage drop across it, so the whole of V appears across L. That makes current begin to flow, and the current creates a magnetic field. The growth of this field induces a back voltage, which is the only thing the voltage applied to L has to face. So the current automatically grows at the rate which induces a voltage equal and opposite to the applied voltage. The inductance L in henries means the number of volts it induces when the current is changing at the rate of 1 amp. per second, or

$$V = L \times \text{amps per sec}$$

So the current starts growing at V/L amps/sec.

Obviously it can't grow beyond V/R_1 amps, because the whole of V would then be occupied in driving it through R_1 and there would be nothing to spare for L. Let T be the time required for the

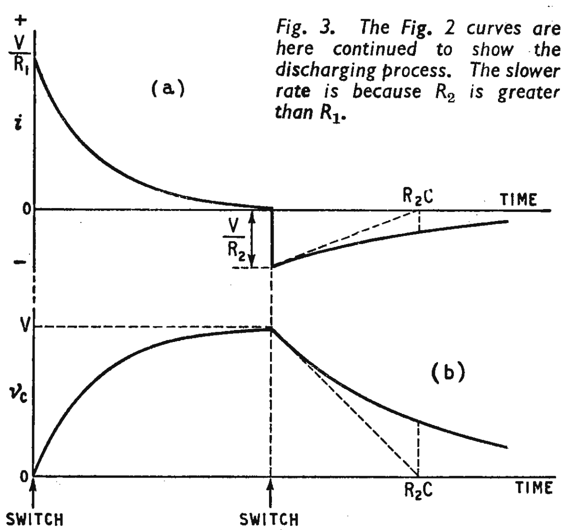


Fig. 3. The Fig. 2 curves are here continued to show the discharging process. The slower rate is because R_2 is greater than R_1.

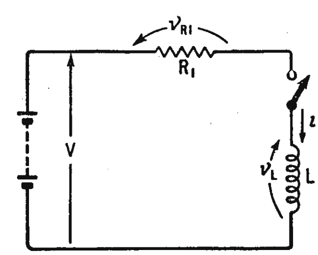
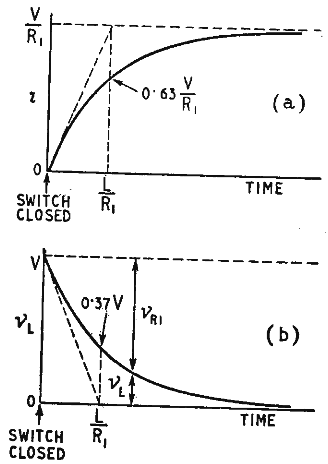


Fig. 4. Inductive counterpart of the first phase of the Fig. 1 experiment.

*April 1952 issue, or Chap. 35 in "Second Thoughts."

Fig. 5. These current and voltage curves for Fig. 4 are the same as the voltage and current curves for Fig. 1 (shown as Fig. 2).



current to grow from nothing to this full amount V/R_1, if it were to keep up its starting rate, V/L. Then the rate of growth is equal to V/R_1 divided by T:

$$\frac{V}{L} = \frac{V}{R_1}/T$$

$$\therefore T = \frac{L}{R_1}$$

This, then, is the time constant for the growth of current in a circuit consisting of L and R_1. Note that the greater the resistance the *shorter* the time for the current to reach its full amount at the starting rate.

Just as the voltage across C could not keep up its starting rate of growth, but eased off into an exponential curve, so with the growth of current in L. Fig 2(b), in fact, would do equally well as a graph of current growth in an inductive circuit. And correspondingly Fig. 2(a) could just as well be a graph of voltage across the inductance during the same period. Clearly T is now the time for the current to reach 63% of its full value, or the transient inductive voltage to decline to 37% of its peak. For comparison with Fig. 2, the LR_1 circuit curves are shown in Fig. 5.

If we try to duplicate the second part of the Fig. 1 experiment with inductance we get into difficulties. Opening the switch in Fig. 4 would (theoretically) make the current change abruptly from its full V/R_1 amps to zero, which is what I said was impossible. It is impossible because an infinite rate of change of current would induce an infinite voltage. What happens in practice is that the voltage rises enough to produce a spark or arc at the switch points, which prolongs the decay of current for a short time after they have separated. If the inductance and the current are large, so that a lot of energy is stored, the result will be spectacular. I remember once in student days pulling out a plug connecting d.c. to the field windings of a large dynamo. If I had happened to be holding the metal parts with bare hands it would probably have been fatal. Nowadays the effect is employed to advantage in generating the thousands of volts needed for the cathode-ray tube in the domestic television set.

As already mentioned, the strict dual of the Fig. 1 circuit is impracticable, because it is not possible to have inductance even approximately devoid of resistance. Short-circuiting a real inductor doesn't keep the current flowing through it indefinitely, as it would if there were no resistance. So the usual Part 2 of the story is to suppose that V suddenly ceases to function, allowing L to "discharge" through R_1. The result, of course, is an exponential decline in current, this current being driven through R_1 by the inductive "kick" caused by that decline of current making the magnetic field linking L collapse. Having already extended Fig. 2 into Fig. 3, you should have no difficulty in extending Fig. 5 to cover this phase of operations, even if you didn't already know it. The time constant, of course, is unchanged, so except for being inverted the curves for this second phase are exactly the same as for the first.

Seeing that all real inductors have some resistance, it will be worth a few moments to consider what effect this resistance has on the voltage waveform one would actually observe in practice. In Fig. 6 the theoretical Fig. 4 is brought nearer reality by inserting r to represent the resistance of the coil. If could of course represent any added resistance as well. Clearly the current curve has the same shape as before, since r might be part of R_1 for all the current knows about it. But to v_L shown in Fig. 5(b) there must be added a component proportional to the current i, as in Fig. 7(a).

If there were some inductance mixed up with R_1, its voltage waveform would cease to be an exact copy of the current, Fig. 5(a), and would be mixed with some of Fig. 5(b), as in Fig. 7(b). In fact, if the time constant of R_1 and its inductance were made the same as that of r and L, the voltage waveforms of both would be flattened out, free of any transients, just as if there were no inductance anywhere, notwithstanding that the current waveform would still grow exponentially from zero.

And now we come to the bits that may not all be quite so familiar. For dealing with the blocking oscillator we shall have to take account of what happens when there is another circuit inductively coupled. To simplify matters let us suppose that the second coil in Fig. 8 has the same number of turns as the first, and that the coupling is 100%, which means that all the magnetic flux due to

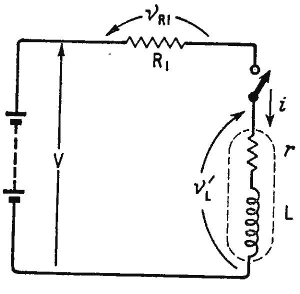


Fig. 6. A real inductor includes some resistance, shown here as r, as well as inductance L.

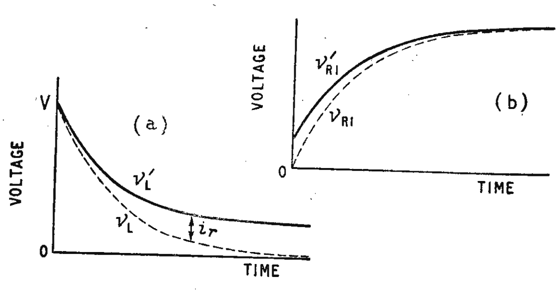


Fig. 7. (a) Showing how the curve of voltage across inductance (Fig. 5(b)) is modified by the resistance r in Fig. 6. (b) If some inductance were to be added to R_1 in Fig. 4, the curve of voltage across it (v_{R1}) would be modified to such as v'_{R1}.

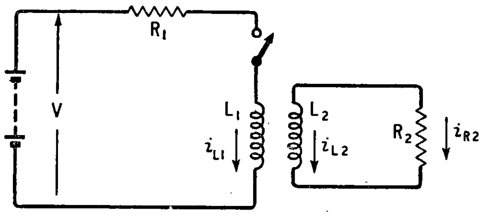


Fig. 8. Addition of a resistance-loaded secondary coil to the Fig. 4 experiment.

current in one coil links both equally. In practice this condition can be nearly attained by using a high-permeability closed iron core. (The amount of magnetic flux is then not strictly proportional to the current, but for our simple study we shall assume that the current is not large enough for this effect to be important.)

Suppose we now set up a voltage across L_1, say by closing the switch and starting a flow of current. The voltage thereby induced in L_2 causes current to flow through R_2. This current also flows through L_2, and affects the flux and therefore the voltages induced. It looks as if we are faced with a vicious circle which will make calculating the upshot of the whole thing very complicated.

Thanks to our forethought in choosing equal turns and 100% coupling, however, it is actually quite easy. The result of these conditions is that whenever the amount of flux in the core changes, the change affects both coils equally, inducing equal voltages in them. And the flux that does this is not due to current in either coil separately, but the resultant of both currents. So it makes no difference to the behaviour of the system shown in Fig. 8 if the two coils are merged into one, as in Fig. 9. True, we can no longer distinguish between the two currents actually flowing in L_1 and L_2; we now know only the resultant of both, but since that is what creates the magnetic flux it is all we need. For example, if the current through L_1 at any given moment is 3A and the current through L_2 is −2A (i.e., 2A in the direction opposing the flux due to the 3A), the equivalent is 1A through L. Note that the −2A in L_2 goes through R_2 in the same direction as if +2A came direct from the source of the 3A, as shown in Fig. 10.

This amalgamation dodge is a great help. Instead of having to embark on a tricky lot of calculations, with secondary current affecting the flux due to the primary and hence the induced voltage, etc., we can see at once that when the switch in Fig. 9 is closed (and before current has had any time to build up through L) the current $i = i_{R2} = V/(R_1 + R_2)$, and the voltage v_L is $VR_2/(R_1 + R_2)$. R_1 and R_2 act simply as a potential divider. After a long time, when the current through L is fully grown, so that the voltage across it—and of course across R_2—has died down to zero, V is occupied solely against the resistance, R_1 so $i = i_L = V/R_1$, and $i_{R2} = 0$. So the finishing line for current is the same as in Fig. 5(a), but the starting line for voltage is lower than in Fig. 5(b).

The only other thing we need know in order to complete the curves as modified by R_2 is the time constant. Before going any farther, try guessing how R_2 will affect it. My first line of argument was that loading a transformer secondary with resistance

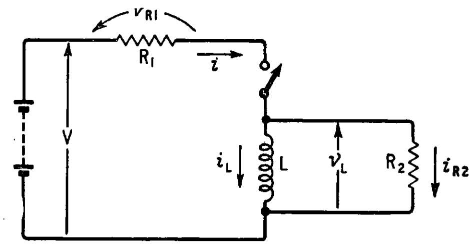


Fig. 9. On the assumption that L_1 and L_2 have equal numbers of turns, coupled 100%, Fig. 8 can be simplified by merging the two coils into one, as here.

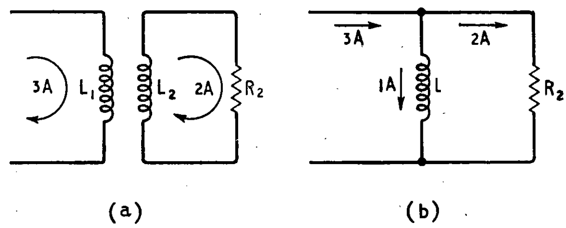
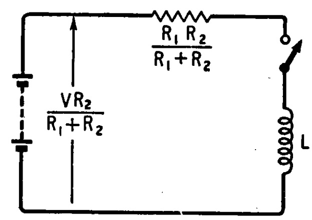


Fig. 10. This comparison shows how opposing currents through L_1 and L_2 are equivalent to their difference flowing through L.

Fig. 11. For purpose of calculating the time constant, Fig. 9 can be further simplified by Thévenin's theorem to the same circuit as Fig. 4 but with different values.



makes the whole thing less inductive from the viewpoint of the supply; time constant is proportional to inductance, so connecting R_2 shortens it. Well, let's see.

But how? Even the simplified equivalent circuit, Fig. 9, doesn't give a very obvious lead towards how to set about it. Fortunately the problem is an easy one—if we remember Thévenin's theorem*. According to this, the system to which L in Fig. 9 is connected can be replaced (so far as L is concerned) by a simple source and series resistance—exactly as in our original inductive circuit, Fig. 4, in fact—in which the voltage of the source is what appears across the gap when L is removed, and the series resistance is the resistance that would be measured across that gap if any e.m.fs. ceased to act. We have already calculated the equivalent source voltage; it is of course the proportion of V that appears across the R_2 part of the potential divider $R_1 + R_2$; $VR_2/(R_1 + R_2)$. And the measured resistance is R_1 and R_2 in parallel: $R_1 R_2/(R_1 + R_2)$. So the circuit which is equivalent to Fig. 8 for the purpose of calculating the time constant is Fig. 11. Instead of L being divided by R_1 as in Fig. 4 it is divided by R_1 and R_2 in parallel—a lower resistance—so is *greater* as a result of connecting R_2. I still find this rather surprising.

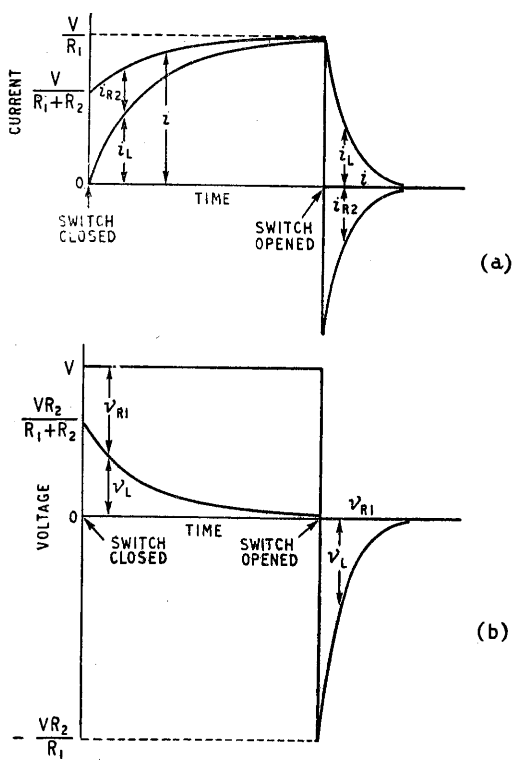
Although Fig. 11 is equivalent to Fig. 9 or 8 when the switch is closed, it obviously isn't when the switch is opened; for further consideration of our

*March 1949 issue, or Chap. 32 of "Second Thoughts".

loaded transformer we revert to Fig. 9. You will remember that we couldn't draw curves or do any thing definite like that about the consequences of open-circuiting the simple inductor in Fig. 4, because theoretically it is impossible. The current through an inductive circuit cannot be changed instantaneously from one value to another. The same applies when L_2 is added. But when R_2 is connected, Fig. 9 makes clear that the current through the inductor doesn't have to change suddenly even when the switch is flicked open; it can continue flowing—through R_2. In fact, adding L_2 and R_2 to Fig. 4 provides a close analogy with the two-way switching in Fig. 1; the effective "charging" resistance in the "make" position is R_1 and R_2 in parallel, and the "discharging" resistance in the "break" position is R_2. The only thing is that the time constant in the second position is bound to be shorter, whereas with Fig. 1 we could do as we pleased.

If we look again at Fig. 8 instead of Fig. 9 we realize now that the current through L_1 *can* cease instantly, without any nonsense about an infinitely high induced voltage. This is the second possibly surprising thing, because at first glance it seems to contradict a basic principle. It probably has a bearing on perplexities experienced in the study of blocking oscillators and pulse circuits generally. The explanation of the paradox, of course, is that the cutting off of current through L_1 is exactly neutralized by an equal and opposite current change in L_2. In terms of Fig. 9, it means that there is no sudden change of current through L. Another way of putting it is that the magnetic energy built up by current in one winding of an inductor, and which would manifest itself as a flash or shock or the like if dispersed abruptly, can be safely and silently "discharged" by a pulse of current entirely in a separate winding.

Fig. 12. Current and voltage curves for the Fig. 9 circuit.



Although so far everything has been going very smoothly, it is quite easy to trip up over the details; and as this is going to be the crux of the matter next month it will be worth recording graphically what we have found about the whole Fig. 8 experiment.

First of all we shall do it on the basis of the simplified circuit, Fig. 9, and then analyse the combined current through L into its separate L_1 and L_2 components.

Let us deal first with the "switch closed" phase. We know (from Fig. 11) that the current i_L through L begins from zero and rises exponentially towards V/R_1 with a time constant $L(R_1 + R_2)/R_1 R_2$, so that can be plotted (Fig. 12(a)). The corresponding voltage v_L can then be plotted, for the time constant is of course the same, and the starting point is $VR_2/(R_1 + R_2)$. Having settled L we must shift our attention back to Fig. 9 for R_1 and R_2. Voltage V is easy, because it is constant. And the difference between V and v_L gives us v_{R1}. That completes the first half of the voltage diagram, Fig. 12(b). The current i follows from v_{R1}, being directly proportional to it ($= v_{R1}/R_1$), so we can plot that. And since $i_{R2} = i - i_L$, i_{R2} appears in Fig. 12(a) as the difference in level between the already plotted i and i_L curves.

Before opening the switch let us analyse i_L into i_{L1}, and i_{L2}. This is easy if we remember that i_{L1} is i (see Fig. 8) so can be plotted in Fig. 13 direct from Fig. 12(a). And i_{L2} is *minus* i_{R2}, so can also be derived from Fig. 12(a), or alternatively from the definition of i_L as $i_{L1}+i_{L2}$ (Fig. 10), curves of i_L and i_{L1} being already available. The interesting thing to note is that current springs instantaneously to the value $V/(R_1+R_2)$ in both coils L_1 and L_2 directly the switch is closed; this is possible because the magnetizing effects of these currents exactly cancel out. Magnetic flux then grows gradually owing to i_{L1} increasing and i_{L2} dying away.

When the switch is opened, i promptly ceases and remains ceased. So that current is easily shown in Fig. 12(a). And so is v_{R1}in Fig. 12(b). The current flowing through L must at first be the same as it was just before the switch was opened —practically$=V/R_1$. It declines exponentially to zero, with a time constant that is clearly L/R_2. That is less than with the switch closed, so we must show it dying away quicker than it grew. And because $i_{R2}=-i_L$ we plot it as a perfect reflection of i_L.

Right at the end there is a possible catch—or

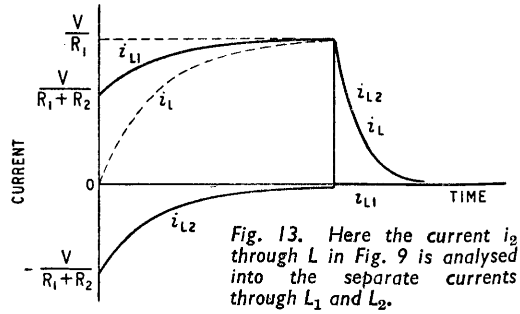


Fig. 13. Here the current i_2 through L in Fig. 9 is analysed into the separate currents through L_1 and L_2.

even two catches—if we are over-confident. Our v_L is clearly the same thing as the voltage across R_2, and that (as every student of Ohm knows) is exactly proportional to i_{R2}, which we have plotted. So we must give v_L the same shape. But seeing i_L positive in Fig. 12(a), and perhaps with $i_{R2} = -i_{L2}$ still (though irrelevantly) in mind, there is just a chance that one might hastily show v_L positive in the second half, as in the first. If studying the directions of the arrows in Fig. 9 doesn't keep us correct in this matter, the fact that the voltage across L must clearly change sign when increase of flux changes to decrease will surely do so.

Even now one might be tempted to copy the first part of the v_L curve in amplitude, though reversing it in sign. If so, we ought to be warned by seeing the negative " half-cycle " smaller than the positive, owing to its shorter time constant. The truth is, of course, that this shorter time constant means that the flux is collapsing quicker than it grew, so the induced voltage is greater at " break " than at " make "; and if you work it out you will find that the negative peak of v_L is equal to VR_2/R_1. So what the negative half-cycle lacks in duration it exactly makes up in amplitude. That this is so can be seen even more directly by comparing the amplitude of i_{R2} at " break " and " make."

The second part of Fig. 13 has no catches, for we have a curve of i_L in Fig. 12(a), and i_{L1} is zero all the time, so i_{L2} must be the same as i_L.

If you are just beginning to get interested, you could do a little homework for next time by thinking out how these waveforms are modified if the ideal transformer we have been assuming is brought one step nearer reality by making its coupling a little less than 100%. This can be represented by a small amount of uncoupled inductance (" leakage inductance ") in series with each winding.

Third International Instrument Show

Exhibits by 54 Firms from Nine Countries

THIS exhibition of mainly electronic instruments, organized by B. & K. Laboratories, Ltd., differs from the too-many others in the field by its international character. It, therefore, provides an opportunity for inspecting apparatus much of which is unfamiliar, and for making comparisons with home products. The setting this year (March 25-29) at the Caxton Hall, London, enabled the exhibits to be examined in comfort.

The following report is confined to apparatus not seen at last year's Show. The nationality of the firms mentioned, where not stated, is American.

The Ampex Corporation specializes in tape recorders, but in contrast to last year's exhibits of sound recorders mainly for entertainment they demonstrated highly developed machines for data storage. One shown uses half-inch tape, with a choice of six speeds from 1⅞ to 60 in/sec, and up to 14 tracks. At the highest speed the frequency response is 100 to 100,000 c/s. By the use of multiplex, over 1,000 channels of simultaneous data can be recorded. In one of several available recording techniques, the small residue of variation inevitable with such a medium as plastic tape is excluded by recording a sinusoidal reference signal, the frequency of which can be stabilized to within almost any desired limits; the recorded data, in the form of frequency ratios relative to this standard, are immune from variations in tape speed. Such recording machines are now being widely used, especially in armament research and in conjunction with computers.

The same firm has produced, but was unable to spare a sample to show, a " Videotape " recorder for television, with a frequency response from 0 to 4 Mc/s. This machine uses 2-in tape at the remarkably low speed of 15-in/sec. Instead of a fixed recording head, producing a longitudinal track, four heads are mounted in a rotating drum and scan the tape, which is brought into contact with the drum throughout its width. Sound is recorded conventionally along one edge of the tape, and there are two tracks along the other edge for cues and editing markers. The usefulness of such machines in television broadcasting is obvious, and it is understood that six are already on order for Britain.

A large proportion of the Bruel & Kjaer (Denmark) instruments on show were concerned with audio testing. As reported briefly last year, they are especially suitable for performing such tests rapidly and automatically, and this year the range has been extended. One key unit is a continuously motor-driven beat-frequency oscillator, 20 to 20,000 c/s, the output of which, through the equipment under test, may be observed on a valve voltmeter scale, a long-persistence c.r. screen, a cartesian or polar recorded diagram, or any combination of these. Other instruments enable an output or response to be selectively analysed. By means of a mechanical coupling between the oscillator-recorder and a slowly rotating turntable, the automatic plotting of a microphone polar diagram was demonstrated. Reverberation diagrams of an auditorium over the whole a.f. range can be taken completely automatically. Hearing aids can be checked visually and/or on paper for amplitude/frequency characteristics in a few seconds; and, by successively coupling a selective detector to multiples of the source frequency, the various harmonic distortions can also be automatically plotted. One of the completely new instruments was for measuring the acoustic absorption coefficients and complex impedances of materials by standing waves in an acoustical transmission line.

Signal analysis by frequency scanning was shown by Panoramic Radio Products and by Kay Electric Co. The former have three models of scanning superhet receiver, with band frequencies of 200 kc/s, 1 Mc/s and 10 Mc/s; and the latter a sweeping oscillator within the band 10 to 350 kc/s, the repetition frequency being adjustable from 0.5 to 2 c/s.

Testing of the ability of electronic equipment to stand up to vibration is now of great importance, and perhaps the most massive exhibit in the Show was a "vibration exciter" by M. B. Manufacturing Co., capable of imposing a test force of up to 3,500lb over the range 2 to 2,000 c/s. This is not the largest by this firm, however; one model is rated at 12,500lb over the same frequency—nearly six tons!

Humidity is another factor in equipment testing, and hygrometers for measuring it are not on the whole very satisfactory. The introduction by El-Tronics of a plastic whose electrical resistance is proportional to relative humidity, the temperature coefficient being quite small, is, therefore, most interesting. Hygrometers embodying it were shown.

Work on colour television necessitates accurate measurements of phase angle. This is one important use of the Type 205A phase detector by Advance Electronics. A variable delay line is used to delay the unknown for a sufficient time to obtain a reading on an output indicator. The unknown phase angle or time delay is read off the dials of the delay line.

For providing action delay of the order of seconds, the relays by Electronic Speciality Co. are useful. They are available in three classes: less than 0.5 sec, 0.5 to 5 secs, and over 5 secs.

A number of new voltage stabilizers were to be seen, one by H. Struers (Denmark) being unusual in providing an electronically stabilized source of a.c. for heaters, etc., up to 4-5 amps in the range 5.8 to 8.2 volts, to limits of 3-4 mV. An h.t. stabilizer was convincingly demonstrated by rapidly varying the input voltage over 20 volts or more and showing that the variation in output voltage was 1 mV or less; this is achieved by a combination of saturated-iron and electronic techniques.

The well-known "Unipivot" range of instruments by the Cambridge Instrument Co. (U.K.) has been extended by a r.f. milliammeter for use up to 10 Mc/s, having five vacuo-junctions selected by a range switch without breaking the circuit.

Valve voltmeters shown last year were notable for low ranges—in one case reading down to fractions of a microvolt. This time attention was attracted by a model with five ranges, the lowest f.s.d. being 5 kV and the highest 100 kV. The most impressive parts, not surprisingly, are the terminals; they are both of e.h.t. type, for the instrument is arranged to measure the vector sum of two phases.

It was unfortunate that customs difficulties held up the appearance of a decade resistance box by Electro-Measurements, for they have brought a new look to this usually stereotyped piece of equipment by arranging as many as six decades concentrically. The dials can thus be easily handled and read off, and much panel space is saved.

Progress in design and applications of transistors was noticeable; for instance, germanium tetrodes by Texas Instruments with a cut-off frequency as high as 200 Mc/s, and silicon transistors by this firm and also by Raytheon.

In the valve department, the most interesting examples were some of the types for microwaves. Several travelling-wave tubes for S-band and X-band were shown by Huggins Laboratories with a small-signal gain of 30-35 dB over a 2:1 frequency band. The Sperry t.w. tube for the L-band (around 1,300 Mc/s) has a peak output of 7 kW, at which the gain is 34 dB. Sperry also showed a klystron power amplifier with a peak output of 15 kW at 2,700-2,900 Mc/s and examples of the new uses of ferrites in microwave circuits.

Other interesting microwave equipment included the standing-wave detector, by the P.R.D. Co., for 100 to 1,000 Mc/s. Instead of the lengthy slotted line usually needed for these frequencies, it is a compact unit weighing only $4\frac{1}{2}$lb, consisting of a coaxial tee junction, a manually driven pick-up probe assembly and a normalizing standard reactance. The angle of reflection coefficient is directly read off a dial after it has been set to minimum indication on the associated meter. The De-Mornay Bonardi range of microwave equipment was notable for the very high frequencies provided for—from 5,800 to 90,000 Mc/s.

A noise-factor meter for both low and high radar frequencies was shown by Magnetic AB (Sweden). The source of noise is, for 5 to 300 Mc/s, a noise diode, and for 1,200 to 12,400 Mc/s a gas discharge tube. The source is electronically switched on and off, and the noise fed into the amplifier under test. A train of pulses of two different amplitudes, corresponding to noise-on and noise-off, is obtained, and the amplitude ratio is measured by an indicator directly calibrated in noise-factor dB. In this way it is possible to adjust equipment to minimum noise factor.

CLUB NEWS

Birmingham.—J. Walker (G5JU) will demonstrate the Eddystone 888 receiver to members of the Midland Amateur Radio Society on May 21st. Meetings are held on the third Tuesday of each month at 7.30 at the Midland Institute, Paradise Street. Sec.: C. J. Haycock (G3JDJ), 360, Portland Road, Birmingham, 17.

Bury.—At the May 14th meeting of the Bury Radio Society M. Barnsley (G3HZM) will give a talk on direction finding. The club meets on the second Tuesday of each month at 8.0 at the George Hotel, Kay Gardens. Sec.: L. Robinson, 56, Avondale Avenue, Bury, Lancs.

Derby.—The Derby and District Amateur Radio Society's programme for May includes an open evening, sale of surplus gear, a visit to a place of interest, and the showing of the Mullard film strip "Indicating Instruments." Meetings are held each Wednesday at 7.30 at 119, Green Lane. Sec.: F. C. Ward (G2CVV), 5, Uplands Avenue, Littleover, Derby.

ARMORIAL BEARINGS have been granted to the British Institution of Radio Engineers. The shield, which is surmounted by the head of Mercury, alludes to Clerk Maxwell and Hertz and the supporters to the 7th Duke of Devonshire (who endowed the Cavendish Laboratory, Cambridge) and Earl Mountbatten, vice-president of the Institution since 1950.

Airborne Doppler Navigation

Radio Application of Well-known Sound Effect

By G. E. BECK*, B.Sc.(Hons.), A.M.I.E.E.

THE classical method of navigation is by steering a compass course, and using the ship's measured rate of progress along that course to fix its position. Allowance for the effects of sea currents and wind is based on their estimated values, and is corrected by occasional observations of the sun or stars. This is the " dead reckoning " which is always adequate for long voyages by sea.

When navigating in aircraft there is little time, and often no opportunity, to make the astronomical checks. But the wind velocity is so large a factor that dead-reckoning methods must take it into account. The compass heading differs from the track actually followed by the aircraft, and the speed over the ground is not equal to the speed through the air. Fig. 1 shows the triangle of velocities concerned.

The drift angle may amount to 30° for a moderately slow aircraft flying in a high wind, and so it is necessary to solve the triangle if navigation is to be accurate. The compass heading and the speed through the air are not enough by themselves.

This has led to navigation systems being devised which are based on radio transmissions from the ground, enabling the aircraft to fix its position at frequent intervals. For example; the radio compass giving bearings from m.f. transmitters, or by the hyperbolic systems such as Gee which lay down a signal pattern, and reference to appropriate charts gives the geographical position.

Self-contained Aids.—Difficulties of securing international agreement on the use of any one system, and the large capital cost of ground installations, make the idea of a self-contained navigational system on the classical model very attractive. For military use a ground-based system which would be prone to jamming, or unavailable over hostile territory, is not in any case a satisfactory solution.

One way out of this difficulty is to make use of the principle known as the Doppler effect. This is familiar, as stated by the Austrian physicist whose name it bears, as the apparent change in pitch of a vibration, when its source is moving towards or away from the observer. The railway engine's whistle drops its note as the train passes the station and its advancing velocity is changed to a receding one.

In Doppler navigation a radio transmission replaces the sound. It is directed downwards from a radar set on the aircraft and the returned echo has its frequency measured. This frequency will be changed

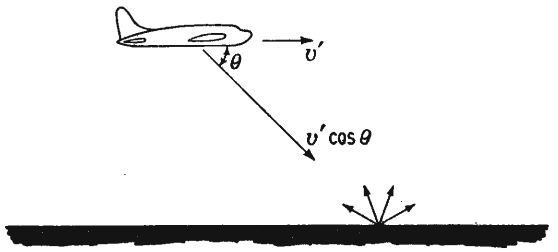


Fig. 2. The ground reflected signal has frequency difference proportional to the component of the aircraft speed in the direction of the radar beam.

from that of the outgoing signal by the Doppler effect, the difference being proportional to the component of the aircraft speed, in the direction of the radar beam[1]. (Fig. 2.)

The speed is that over the ground, which is one missing factor in the solution of the dead-reckoning calculation. The other factor, the drift angle, can be measured by a second beam directed laterally. This will give the sideways component of the aircraft's ground speed. Alternatively, the beam can be rotated until it lies in a direction for which the Doppler effect is a maximum. It must then lie along the track being followed by the aircraft, and the drift angle is directly measured by the azimuth angle between the beam and the aircraft fore-and-aft line. Compass heading, drift angle and ground speed are together sufficient for the navigation problem to be solved. It is in fact not necessary to determine the air speed or wind velocity.

The Doppler Equation[2].—A picture of the mechanism by which the Doppler effect is produced can be made by referring to Fig. 3, where c is the velocity of propagation. The radar set moving with velocity v towards a target will transmit, in a time t, a wave which occupies a radial distance $c.t$.

This portion of the wave, which is approaching the target with velocity $c + v$, will be reflected in a time:—

$$\frac{c \, . \, t}{c + v}$$

* Marconi's Wireless Telegraph Company, Ltd.

[1] British Patent No. 638167.

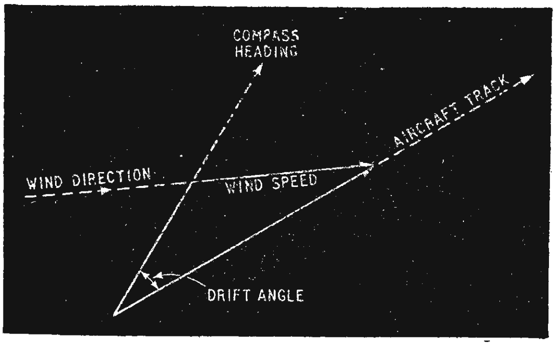


Fig. 1. Triangle of velocities for determining true course of aircraft.

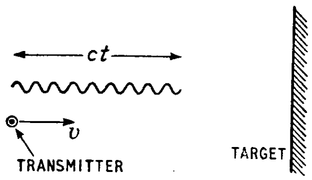


Fig. 3. Mechanism by which Doppler effect is produced.

During this time the radar set will have moved a distance:—

$$\frac{v.\,c.\,t}{c+v}$$

and so the last part of the echo will have this distance less to travel, and will take a time:—

$$\frac{v.\,c.\,t}{c+v}\cdot\frac{1}{c}\text{ less,}$$

that is, the echo will be received in a time:—

$$\frac{c\,.\,t}{c+v}-\frac{v\,.\,t}{c+v}=\frac{c-v}{c+v}\cdot t$$

In this time the number of cycles received will be the same as that transmitted in time t. Therefore the frequency observed will be $(c+v)/(c-v)$ times the transmitted frequency.

For a transmitted frequency f, the frequency change is:—

$$\frac{c+v}{c-v}\cdot f - f = \frac{2v}{c-v}\cdot f \approx \frac{2vf}{c}$$

since $v \ll c$.

As shown in Fig. 2, the aircraft ground speed is v', where $v' \cos\theta = v$ and so the measured Doppler frequency is:—

$$f_D = 2\frac{f}{c}\cdot v'\cos\theta$$

This is the basic Doppler equation, from which the ground speed is derived by measurement of f_D.

Practical Figures.—Some elementary calculations can be made to show the technical problems involved. For shallow angles of incidence (θ) only a small part of the incident energy will be scattered back in the direction required for reception, while with a steep angle $\cos\theta$ will be small, and the value of f_D will be too small for precise measurement.

If $\cos\theta=\frac{1}{2}$ is a suitable compromise, we have, for an aircraft speed of 600 m.p.h. or $\frac{1}{6}$ miles per second:—

$$f_D = \frac{f}{6\times 186{,}000}$$

or about 1 part in 10^6 of the transmitted frequency.

As a direct frequency measurement this would be difficult but by heterodyning the returned echo with the transmitter frequency, f_D can be extracted as a beat note. Taking $f=5.2\times10^9$ c/s (5.7 cm wavelength) $f_D\approx 5$ kc/s, which is an audio frequency capable of precise measurement.

This waveband is a very suitable one in view of its propagation characteristics, the established airborne radars working in it, and the possibility of a narrow beam without excessive aerial size[3].

A narrow beam is clearly necessary to give a finite value to θ in the Doppler equation. Even with microwaves the width is not likely to be reduced below 3° or 4°, so that the Doppler frequency will not be a single tone, but a spectrum having a width, for a 4° beam centred on $\theta=60°$, of:—

$$\frac{\cos 58° - \cos 62°}{\cos 60°} = 12\%$$

The Doppler frequency corresponding to the ground speed will be the centre of this spectrum, and one major technical problem is the measurement of this centre with sufficient accuracy.

Power Requirements.—Assuming a flat earth illuminated at vertical incidence by a transmitter-receiver at height h:—

$$\frac{P_R}{P_T} = \frac{G^2\lambda^2}{16\times\pi^2(2h)^2}$$

where

P_R = power received.
P_T = power transmitted.
G = aerial gain.
λ = wavelength.

With an aerial gain of 120, $\lambda=5.7$ cm, $h=50{,}000$ ft:—

$$\frac{P_R}{P_T} = \frac{120^2\times5.7^2}{16\times\pi^2\times10^{10}\times30{\cdot}4^2}$$
$$=3.2\times10^{-10} = -95\text{ dB.}$$

Due to scattering and oblique incidence on the ground, the received signal will be less than this, and experimental results show[4] that the additional loss is of the order of 50 dB.

The total system attenuation is therefore 145 dB at this altitude, and the transmitter power must be sufficient to give a detectable signal in these conditions.

Receiver Sensitivity.—The receiver noise power is 0.4×10^{-14} watts per Mc/s bandwidth. This power is produced in the receiver input circuits at room temperature. This must be increased by the noise figure to find the signal required for unity signal/noise ratio at the second detector. Although the post detection signal/noise ratio can be greatly increased in view of the narrow band of audio frequencies which carries the Doppler information, intermodulation noise products prevent a much smaller signal being used.

For a 5.7-cm superhet receiver we assume a noise figure of 13 dB, a bandwidth of 1 Mc/s and the resulting signal power (P_R) required is 8×10^{-14} watts. The transmitter power is therefore 145 dB above 8×10^{-14} watts, or 25 watts.

Pulse Transmission.—The power suggested is not outside the range of modern microwave c.w. valves, but pulse methods are worth examining, in view of the established techniques using magnetrons for airborne use.

We must have a pulse repetition frequency high enough to avoid false Doppler signals from the p.r.f. or its harmonics. Also the time taken by the pulse to reach the ground and return prevents the echo, and the transmission, from being available simultaneously for the necessary heterodyning to extract the Doppler beat note. This last point is covered if we transmit pulses simultaneously in both forward and backward directions, and obtain the Doppler beat by mixing the two echoes[1].

In the forward direction the frequency will be increased, and in the backward it will be decreased, by the amount given in the Doppler equation.

[2] See "Radio and Radar Technique," A. T. Starr, p. 51 (Pitman).
[3] *Electronics*, September 1955, p. 178.
[4] "Radar Echoes at Centimetre Wavelengths," Davies and MacFarlane, *Proc. Phys. Soc.*, 1946, Vol. 58, p. 717.

The beat frequency will thus be twice that in a "single-ended" system.

Assuming a top speed of 600 m.p.h. the Doppler frequencies will go up to 10 kc/s and the p.r.f. must then exceed 20 kc/s if neither the p.r.f. nor p.r.f. minus true Doppler signal is to give a false signal. This repetition rate is many times higher than in normal magnetron applications, and to avoid over-running the magnetron it has to be considerably de-rated, or run on an intermittent cycle. Twenty-five watts mean power at 20 kc/s p.r.f. with $\frac{1}{2}$-μsec pulses implies a peak power of 0.6 kW. This is a modest size for airborne pulse magnetrons.

Presentation.—The measured Doppler frequencies can be shown directly to the navigator on a dial calibrated in ground-speed knots, and the drift angle similarly presented if a moving aerial system is used to set the beams along the aircraft's track line as described. Alternatively, if these quantities, together with compass heading, are fed into a simple computer, it will calculate the present position of the aircraft continuously. The results can then be shown as latitude and longitude, if the appropriate values are set in at the beginning of a flight.

For civil use more complex calculations are possible, relieving the navigator of much routine work. On a given flight plan the route and destination can be set in before take-off, and the calculations performed to show continuously distance to destination, departure from track, and estimated time of arrival.

Size and Weight.—An airborne equipment of the form described can be expected to weigh something of the order of 200 lb and consume 1 to 2 kW total power. The aerial system requires a radome, but since the beams are directed wholly downwards the scanner can be mounted within the airframe, with the radome flush with the skin. For the beam width discussed the aperture should not exceed 3ft in any dimension.

Accuracy.—To be of significant value, the computed accuracy of positions found by this dead-reckoning technique should be within one or two per cent of the distance travelled. With 1% error, after a 2,000-mile flight the aircraft will know its position within 20 miles. At that stage the local air traffic control will have taken over and the long-range navigational aid is no longer required. A corresponding accuracy of e.t.a. is a major improvement on existing standards, and would greatly help the control of air traffic on the civil airways. But perhaps enough has been said of its possibilities to show that airborne Doppler equipment may be a major factor in long-range navigation.

AIRBORNE WEATHER RADAR

Storm Warning Indicator and Navigational Aid

WEATHER radar is an appropriate description for the Bendix Type RDR1 aircraft installation as its primary function is to give information regarding the nature of cloud banks along the flight path and advanced warning of hazardous areas where severe air turbulence is likely to be encountered. A secondary, but no less useful, function is the facility for mapping the ground along the flight path. This equipment was shown at Farnborough last year by Elliott Brothers but at the time it was not possible to give any details.

It operates in the X Band (3.2 cm) but, if required, it can be supplied for the C Band (5.5 cm). At these very short wavelengths a sheet of water shows black on the plan position indicator (p.p.i.), while land shows white and the terrain mapping facility provided by the 3.2-cm equipment thus enables rivers, lakes and coast lines, and after some experience mountains and high ground, to be recognized and identified.

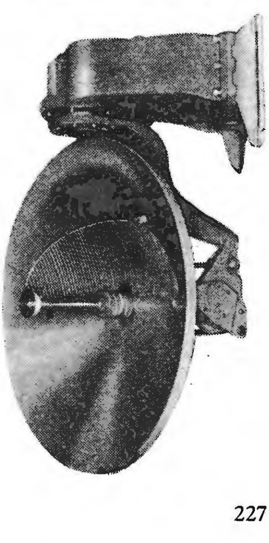
For mapping clouds a pencil beam is employed, but for terrain mapping the beam is converted into a "cosecant-squared" or fan-shaped one. This is effected by changing from horizontal to vertical polarization. Alone this would not affect the beam pattern, as a parabolic-dish scanner is employed. To the upper part of the dish, however, is fitted a grid composed of a series of vertical bars and with vertical polarization they behave as beam-diffusing reflectors, producing a fan-shaped beam in the vertical plane. They are unresponsive to horizontal polarization and the beam shape is then determined by the characteristics of the dish alone.

Switching from horizontal to vertical polarization is effected by utilizing the Faraday rotation properties of certain ferrites on the application of a magnetic field. In this case the magnetic field is produced by passing a current through a coil wound over a section of the wave-guide feeding the aerial "head." Thus no mechanical switching is involved.

The RDR1 has the "Iso-echo" display feature with which the contour within the cloud where the greatest rainfall gradient prevails is outlined and the area enclosed is displayed on the p.p.i. as a black core. These cores represent the danger regions of the cloud bank to be avoided. This differentiation is achieved by arranging for reflected signals exceeding a certain intensity to show as black patches in the midst of the white patches representing normal cloud echo signals.

Other information the aircrew can extract from a weather-radar display is the presence of hail. To do so correctly requires much experience in interpreting the p.p.i. display, as the presence of hail is deducible only from the edge formation of the clouds and not by identifiable variation in the intensity of the returned echoes.

A condensed specification of the X-Band equipment is: 360° scanner rotation at 15 r.p.m. with 240° p.p.i. display; ±15° maximum vertical beam tilt; 0-20, 0-50 or 0-150 nautical miles display; 40 kW peak pulse power; 1.5μsec pulse width; 22in-diameter scanner.



The scanner of the Elliott-Bendix airborne weather radar. The grid for producing the "cosecant-squared" beam for ground mapping is shown.

Limiting Factors in Gramophone

I.—PLASTIC DEFORMATION AND WEAR OF GROOVE WALLS

THE stylus tip in a gramophone pickup is usually spherical and much more rigid than the record, so that the problems of determining the deformation of the record groove wall have much in common with those associated with hardness tests such as the Brinell, in which a ball is pressed into the surface to be tested. Under light loads any material will deform elastically, giving a small area of contact. On releasing the load the material springs back to its original position undamaged. With increasing load, the yield stress of the material will be reached and permanent plastic deformation will begin; on releasing the load the material will not return exactly to its original position, i.e. the record is damaged.

The equations for the elastic range are well known and were deduced by Hertz; they have been expressed in convenient form by Hunt[1].

$$p_m = \frac{0.45\, E_1^{\frac{2}{3}}\, W^{\frac{1}{3}}}{R^{\frac{2}{3}}}$$

$$\text{or } W = \frac{11\, p_m^{\,3} R^2}{E_1^{\,2}}$$

Where p_m is mean bearing pressure between contacting surfaces in kgm/mm²

$E_1 = E/(1-\sigma^2)$
E = Young's modulus of record material (kgm/mm²)
σ = Poisson's ratio of record material
W = Load on stylus in grams
R = Stylus radius in mils (0.001in).

Because of the complex stress system, yielding occurs at a value of p_m = 1.1 times the simple tensile or compressive yield stress of the material. Hunt[1] quotes 11 milligrams as the limiting load for no plastic deformation for a stylus of 1-mil radius on vinyl. Although the stylus is supported by both groove walls at low signal levels, at extreme amplitude or acceleration one wall will be taking most of the load. As this is applied at about 45° to the surface, the playing weight must be increased by $\sqrt{2}$ before yielding can commence, i.e. to about 16 milligrams. In a modulated groove the stylus is in contact not with a flat surface but with concave and convex groove walls. This would reduce the load required for yielding by a factor of 0.77 if the driving wall were convex and the trace radius approached the stylus radius. However, at high frequencies where the trace radius may be small the inertia of the pickup will be a controlling factor rather than the stiffness, so that the load will be taken entirely by the concave outer wall (Fig. 1).

As the load on the indenter (stylus) is increased beyond the elastic range, yielding occurs not at the surface but below, at a distance of about half the radius of the circle of contact. With further increase in load, deformation will gradually spread throughout the area under the indenter. Eventually, plastic deformation of the surface will commence at the surface. With further increase in load, plastic deformation occurs over the whole of the area of contact (the condition has been termed "full plasticity") when the contact pressure is about three times the yield stress of the material. Further increase in load does not appreciably affect the contact pressure. This is the condition in normal identation hardness testing, where the load must exceed the minimum value for full plasticity for reliable hardness readings to be obtained.

From Hunt's results, the minimum load for full plasticity is 6-10 grams with a 1-mil stylus on a vinyl surface (Hunt's Fig. 2). Many commercial pickups therefore operate in the fully plastic range, and must cause considerable damage to the groove (Fig. 2). If each groove wall were deformed equally at all parts of the waveform, this would give no distortion and would not be serious. However, as the load is not taken equally by each wall, the deformation will be unequal, giving distortion of the waveform, with a decrease of low-frequency signals (where stiffness is operative) and an increase of high frequencies (where inertia is operative). Similar effects occur due to the elastic deformation of the groove walls, but in most if not all commercial pickups the elastic effects will be small compared with the plastic. A possible method of obtaining equal deformation of both groove walls would be to play the virgin record first at twice the normal tracking weight at a very low speed, so that the pickup arm could follow the whole of the wave form with negligible lateral loads, but this would hardly be practicable.

The ideal pickup would work entirely within the elastic range (16 mgm). Although it may not be possible to construct such a pickup it might still be possible to limit plastic deformation to the interior of the material, so that the surface of the grooves is undamaged[3]. The limiting tracking weight would be that at which plastic deformation just commenced at the surface. Unfortunately, this point cannot as yet be calculated. Under any stress

[1]Hunt, F. V. *J. Audio Eng. Soc.*, Vol. 3, No. 1, Jan. 1955.
[2]Davies, R. M. *Proc. Roy. Soc.*, Vol. 197, A1050. 22 June 1949

[3]Barlow, D. A. *J. Audio Eng. Soc.*, Vol. 4, No. 3. July 1956.

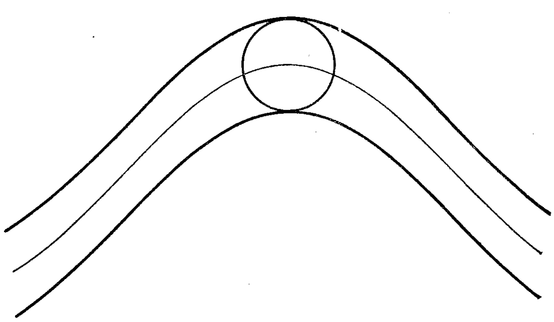


Fig. 1. Stylus supported by convex and concave groove walls.

Reproduction

By D. A. BARLOW, M.Sc.

system, all materials yield according to some function of the shear stress. The shear stress contours in a material under an indenter at the moment of sub-surface yielding are shown in Fig. 3; they will vary somewhat with the Young's modulus and Poisson's ratio of the material. The shear stress at the surface is 0.33 of the shear yield stress, and is proportional to the cube of the load while the whole of the material is elastic. To obtain surface yielding therefore, the load will have to be raised by some unknown factor, probably greater than $(1/0.33)^3$, giving 0.3 gram for a flat surface, or 0.43 gram for a record groove.

As the record moves under the stylus, the system is not the same as the static indentation case so far considered. Poritsky[4] has shown, for cylinders in contact, that the effect of an additional tangential force, as represented by friction, is to shift the point of onset of yielding nearer to the surface. The influence of stylus-groove friction would doubtless be similar and would affect yield loads, but if friction is low, as is probably the case, the effect will be small.

Scratch Tests.—Hunt's scratch tests were conducted by dragging 1-mil and 3-mil radius styli over flat vinyl surfaces. No trace was detected below about 6.7 grams for the 3-mil stylus; the corresponding load for the 1-mil stylus should be 0.75 gram, but no tracks were detected below 1.5 grams, probably because of the difficulty of detecting such very fine traces. The limiting loads for plastic deformation just to appear at the surface with a 1-mil stylus will thus be between 0.3 and 0.75 gm for a flat surface, or 0.4 and 1 gm for a pickup, say, half a gram.

Shellac Records.—From hardness tests, the yield strength of shellac is about twice that of vinyl. From cantilever loading tests, the modulus of elasticity of shellac is about three times that of vinyl. The increased yield stress is therefore more than offset by the increased modulus, giving a smaller area of contact (and hence higher stresses) for a given load. The limiting load for no plastic deformation of shellac will thus be slightly less than for vinyl (for the same size stylus). For a 2.5-mil stylus the load will be about 90 milligrams, and the corresponding load for plastic deformation to just

[4]Poritsky, H. *J. Appl. Mech.*, Vol. 17, No. 2. June 1950

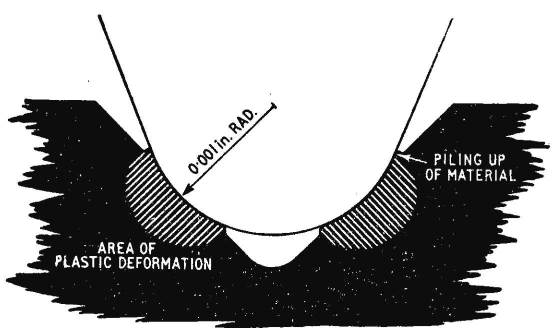


Fig. 2. Stylus-groove contact in the fully plastic range.

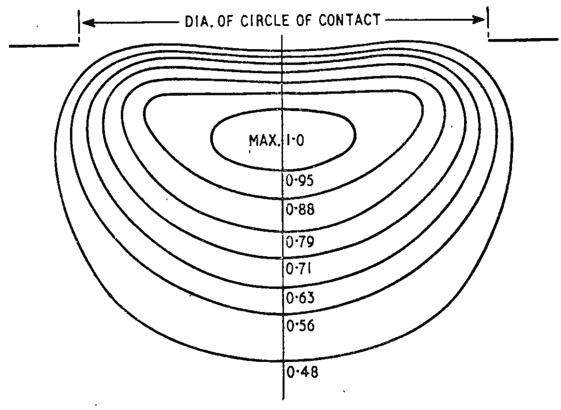


Fig. 3. Shear stress distribution in material under spherical indenter (after Davies[2]).

appear at the surface will be 1.75 grams. Loading tests on shellac with a 2.5-mil sapphire stylus showed tracks at less than 3 grams, corresponding to a pickup weight of about 4 grams. We may thus take the limiting load as about 2½ grams.

It will be noted that at low loads, for a given stylus, shellac will actually be damaged more than the vinyl, but around 15 grams for a 2½-mil stylus the track width or damage will be similar for each material, and above this load the damage to shellac will be less—the track width will be about 0.7 of that on vinyl in the fully plastic range. Shellac is therefore the better material for the old type of heavy pickup, but vinyl will be superior for lightweight pickups. This would explain conflicting reports on the relative damage of vinyl and shellac discs. There is no technical reason why, in these days of lightweight pickups, 78 r.p.m. records should not be made in vinyl.

Deterioration on Repeated Playback.—When any material is deformed the area of contact increases, and, beyond the elastic limit, the material work hardens until it is able to support the load, unless the load is so high as to cause fracture. Once a record has been played at a given weight, provided that this is not too great, there will be no further plastic deformation on continued playback (at the same weight); the record will sound the same as at the first playing, although it may be heavily deformed, and there is no knowing what the virgin record would sound like. The claim that a certain record sounds the same after 1,000 playings as it did with the first playback does not mean that it is undamaged.

It used to be the practice of record companies to monitor the original wax or lacquer disc before plating to make the master. If the original has been damaged in this way, the final record will not sound any different for being played with a very lightweight pickup. It would be interesting to know if the record companies still monitor the original disc before plating now that the original recording is usually done on tape. If we are to take advantage of very light-weight pickups which will not give plastic deformation of the surface not only must we purchase virgin records but it is essential that any monitoring at any stage during manufacture be done with equally light pickups (or with styli that are weaker than the groove walls).

Nevertheless, with heavy pickups progressive deterioration does take place on continued playback. This is due to creep and fatigue. At high stresses the material continues to deform slowly, so that on repeated replay the groove continues to be deformed slightly each time. Fatigue is the fracture of a material by varying or repeated loads at stresses lower than the static strength. As the highest stresses are sub-surface, failure will take place by sub-surface cracking, giving flaking and pitting of the groove walls. This gives the increase in noise characteristic of heavily played records. It is interesting to note that Max[5] obtains this type of failure on repeated playback of polystyrene and occasionally vinyl records at 10 grams load with a 1-mil stylus. If there is a rest period between replays the material partly recovers, and does not fail.

Wear.—Up till now we have been discussing damage or plastic deformation of perfect surfaces, although it is often referred to as wear. Wear may be defined as the attrition of contacting surfaces due to relative sliding. The nature of friction is as follows. Under light loads no two surfaces contact at more than a few high spots or asperities, however accurately thay may be finished. Local pressures at these asperities are therefore high, and ploughing, welding and shearing occur on relative motion. This is the normal mode of wear of styli. If there is no bulk surface plastic deformation of a record, the stylus is supported by the asperities, which may be stronger than the bulk material[1,3] and will give a lower rate of frictional wear of record and stylus than a heavier pickup working in the fully plastic range, where the whole of the mating surfaces are in intimate contact. Diamond is known to give lower coefficients of friction with most materials than sapphire or cemented carbide; it might therefore be expected to give less frictional record wear.

Noise.—The noise level will depend on the tracking weight of the pickup as well as on other factors such as sensitivity for degrees of freedom other than lateral. Also Hunt[1] has pointed out that there are the following components in the noise from a gramophone record.

(1) *Surface roughness.* The grooves of modern records are very highly finished, the roughness as low as 50 A.U. (10^{-7} mm). This is as low as is obtainable on the most highly finished surfaces. In the case of shellac, the filler is of course responsible for considerable roughness, and hence noise. This can be reduced somewhat by the use of superfine fillers.

(2) *Welding and shearing of asperities.*

(3) *The associated plastic deformation.* This may also give rise to noise as plastic deformation is not a continuous process, but on a microscale, it occurs by discontinuous slip.

To reduce wear and noise, therefore, improvements can be made only to items (2) and (3), given a homogeneous record material. In addition to using a diamond stylus, the obvious method would be to use polytetrafluorethylene (p.t.f.e.) for the record[1] or the stylus, although its yield stress and modulus may be too low. This gives low friction with all materials, but if the pickup works in the fully plastic range a coefficient of friction of only 0.04 represents welding of stylus to groove over 25% of the contact area[3]. This will obviously give relatively high wear and noise level, so that the situation with more readily weldable materials, such as vinyl, can well be imagined. Polyethylene usually has a lower coefficient of friction than other plastics (apart from p.t.f.e.) but its yield strength and modulus may be too low; however, Smith[6] has used polyethylene and reports that it gives a lower noise level than vinyl. Polyethylene is said to be too expensive for records; polytetrafluorethylene would be very much more so. It would be interesting to know what proportion of the cost of a record is represented by the plastic and its processing—it has been said that the cost of producing a record pre-war was about 3½d. If so, a more expensive plastic giving lower noise level could obviously be used without appreciably increasing the cost of a record.

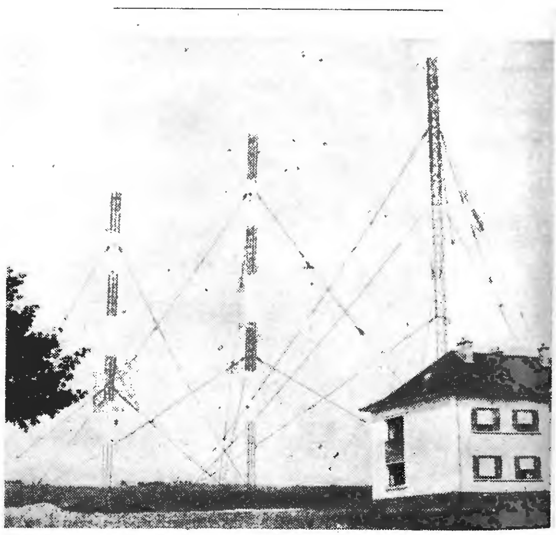
Other possible means of reducing friction would be the use of graphite for styli, or porous metal or ceramic impregnated with graphite, oil or p.t.f.e.

Another method of reducing wear and noise due to items (2) and (3) would be by lubrication of the record[1,3]. For this purpose, a solution of calcium petroleum sulphonate in a light petroleum fraction has been suggested. This would be wiped on to the record immediately before each playing, the solvent evaporating and leaving an adsorbed film, only a few molecules thick, on the groove walls. This would probably give adequate boundary lubrication, and would not obscure the high frequencies. Flake graphite, as has been used in the past, would not be adsorbed on to the groove walls, and would have no effect other than to increase noise by reason of particles trapped under the stylus.

[5] Max, A. M. *J. Audio Eng. Soc.*, Vol. 3, No. 2. April 1955

[6] Smith, O. J. M. *Audio Eng.*, Vol. 32, No. 9. Sept. 1948.

(*To be continued.*)



RADIO LUXEMBOURG recently brought into service two new 100-kW transmitters at Marnach, about 40 miles north of the city. The original 100-kW transmitter is being transferred to the new site from which the three transmitters will then operate in parallel on 208 m.

Technical Notebook

Plug-in Counter Units, designed on the "building block" principle so that a variety of different equipments can be assembled, have been introduced by Ericsson Telephones. Several ranges of units are available, covering counting speeds from 5c/s to 200kc/s. Below 5c/s the counting is done on electro-mechanical registers. Speeds up to 350c/s are obtained on Dekatron units with cold-cathode tube coupling stages. For speeds up to 20kc/s the Dekatron units have thermionic-valve driving stages, while binary units are used for counting speeds up to

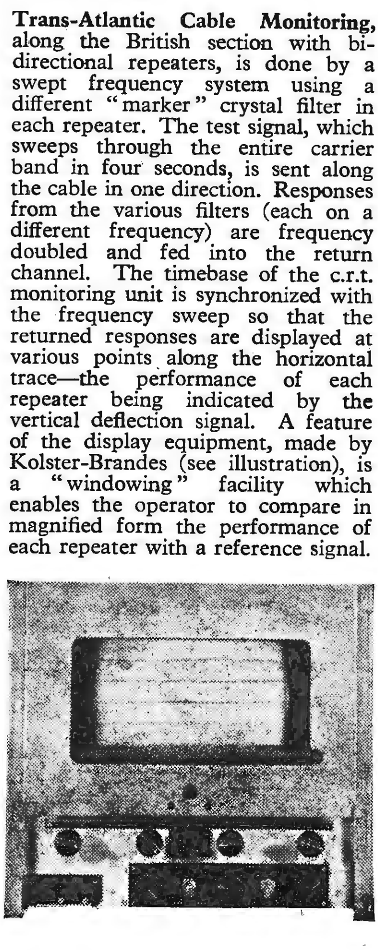
200kc/s. Also available are input, output and control units, and a 1-kc/s valve-maintained tuning fork oscillator designed for timing and tachometry applications.

R.F. Absorption Matting of unusual composition has been developed by W. H. Emerson, A. G. Sands and M. V. McDowell, for use in anechoic chambers to facilitate indoor aerial measurements at lower frequencies. It takes the form of a loosely spun mat of animal hair impregnated with rubber containing carbon black. Reflection is minimized over a wide frequency range by graduating the amount of loaded rubber applied according to the depth of the mat. A 4-inch-thick mat absorbs as low as 1,000Mc/s and an 8-inch version well below 500Mc/s. Further details in D.S.I.R. unpublished report PB114686.

Multiplex Indication System using a single pair of wires has been developed by G.E.C. for checking the operating state of equipment remote from the control point. It utilizes up to twelve transmitter units, consisting of a.f. oscillators tuned to different frequencies, situated at various points along the wires, and a cabinet containing the corresponding receiver units. Each receiver comprises a band-pass filter, amplifier, detector and relay. Thus, when a particular a.f. tone comes on the line, switched by the associated piece of equipment, the corresponding receiver relay operates and shows which transmitter is working. A feature of the system is the use of transistors, and the battery power supply will run for six months on continuous load before replacement becomes necessary. Indicating signals can be sent along wires of up to five miles in length.

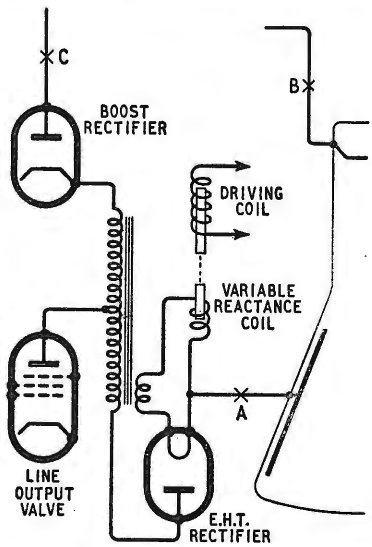
Titanium Oxide Rectifiers are being developed by A. E. Middleton, O. J. Mengali, L. R. Jackson and R. C. Sirrine to give degrees of rectification similar to selenium and germanium but permitting wider temperature variations. Films of oxide are formed on titanium conducting bases and have n-type characteristics. Point-contact rectification is obtained with tungsten, and junction rectification with copper and other metals. A junction rectifier using copper worked satisfactorily up to 280°C. Full accounts of the work are given in D.S.I.R. unpublished reports PB115426 and PB115427.

Trans-Atlantic Cable Monitoring, along the British section with bi-directional repeaters, is done by a swept frequency system using a different "marker" crystal filter in each repeater. The test signal, which sweeps through the entire carrier band in four seconds, is sent along the cable in one direction. Responses from the various filters (each on a different frequency) are frequency doubled and fed into the return channel. The timebase of the c.r.t. monitoring unit is synchronized with the frequency sweep so that the returned responses are displayed at various points along the horizontal trace—the performance of each repeater being indicated by the vertical deflection signal. A feature of the display equipment, made by Kolster-Brandes (see illustration), is a "windowing" facility which enables the operator to compare in magnified form the performance of each repeater with a reference signal.



The push-pull Y deflection output stage is arranged so that when the incoming signal falls outside certain limits (the "window"), the two valves cease to act as a normal amplifier and one of them becomes cut-off. These limits are set manually by the Y gain and shift controls.

Television E.H.T. Regulator, devised by John D. Burke, is intended partly for lengthening the life of e.h.t. rectifiers in line flyback systems and partly for increasing the possible current output and range of c.r.t. brilliance. According to Mr. Burke,

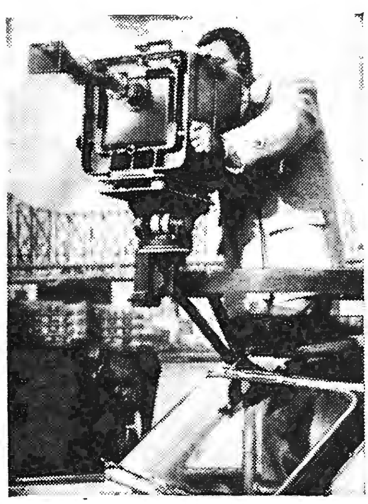


about one-fourth of service calls involve (or are exclusively for) the replacement of e.h.t. rectifiers. He maintains that breakdowns resulting from open- or short-circuited heaters or loss of cathode emission are caused by the rectifier heater growing cooler just when the picture brightness makes heavy demands for c.r.t. beam current. This appears to be inherent in the line flyback e.h.t. system. To combat the effect, the new regulator device has a coil in the rectifier's heater circuit, the reactance of which is varied by the c.r.t. beam current so that an increase of beam current causes an increase of heater current and vice versa. In one version a saturable reactor is utilized, with the beam current passing through the control winding. Another version, illustrated in the sketch, uses a movable armature which is pulled into a driving coil by increasing c.r.t. beam current (against the action of a spring or gravity). This armature is mechanically coupled to a movable core in the variable-reactance coil in such a way that increasing beam current reduces the reactance. The driving coil can be connected into the beam current circuit at any of the points A, B or C marked with a cross.

Fluorescent Noise Source, using a 6-watt fluorescent lamp coupled to a coaxial line, has been devised by M. Hill for monitoring purposes in radar equipments operating in the 400-Mc/s band. It is actually usable over a wide range of frequencies. Details are given in D.S.I.R. unpublished report PB118451.

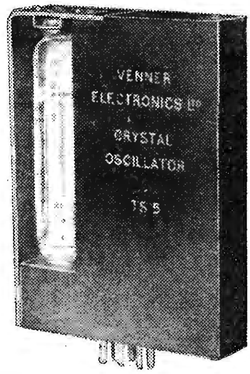
Super Elliptical Speaker, recently introduced in the U.S.A. by Rola, measures 14 inches in one direction and only 3 inches in the other. The ellipticity is accentuated in this fashion so that the speaker can be mounted at the front of a television receiver alongside the picture tube. The performance is claimed to be equivalent to that of an 8-inch circular model.

Miniature Aerial Horn, used by American broadcasting organizations in television "roving eye" microwave transmitters, makes the transmitter operator look very much like his colleague the cameraman. The broad beam of the horn aerial, compared with the parabolic "dish" normally used for this work, permits less critical sighting between the mobile transmitter and the fixed receiver. This is a distinct advantage in maintaining a good signal when the television unit is on the move and has to follow a circuitous route. The 8-inch-long horn (made by Narda) has a beam width of 20° vertically and horizontally. It



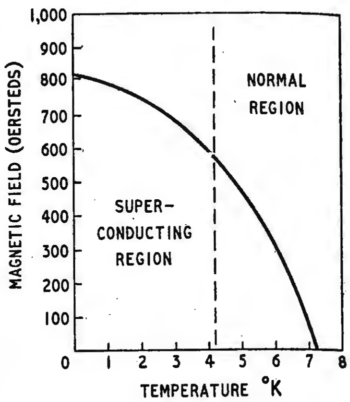
covers a frequency range of 5,850-8,200Mc/s and has a gain of 16.5dB.

Transistorized Crystal Oscillator made by Venner Electronics provides two outputs, one sine-wave and the other square-wave, at a frequency of 10kc/s. The circuit is potted in synthetic resin with the



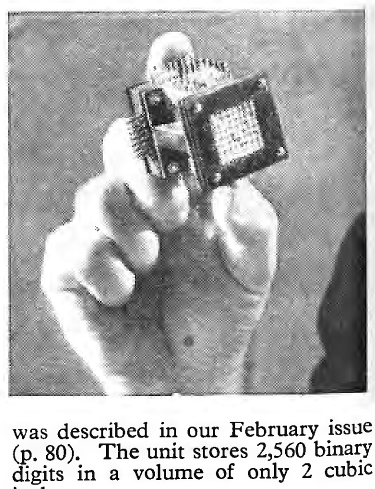
exception of the crystal, which is replaceable. Actually, two types of crystal can be used in the device, one having a zero temperature coefficient between 15°C and 20°C so that maximum accuracy is obtained at room temperature, and the other a zero temperature coefficient between 40°C and 50°C for applications where the ambient temperature is of this order. The stability of the oscillator, at about the point where the zero temperature coefficient occurs, is of the order of 3 parts in 10^6. The supply voltage is nominally 10 but the unit will function satisfactorily with supplies from 4V to 12V. Incidentally, the oscillator can be used in conjunction with the transistorized plug-in decade counter described in our January issue.

Superconductive Computer Elements, developed by D. A. Buck and called "cryotrons," are the basis of a digital computing machine now being built by the A. D. Little company in Cambridge, Mass., U.S.A. The main advantages of the cryotron—virtually a 1-inch wire "core" carrying a small coil—are its extremely small size, simple construction and low power dissipation. In superconductivity, the resistance of a metal suddenly drops to zero when its temperature is reduced below a certain critical value (by immersion in liquid helium). The presence of a magnetic field makes this critical temperature even lower, and the graph shows how a field affects the onset of superconductivity for a "core" made of lead. Thus, a wire held at a constant low temperature can be switched between superconductivity and normal resistivity (up and down the dotted line) by means of an energizing coil—thereby providing a two-state device suitable for binary arithmetic. A flip-flop using two cryotrons is shown in the



lower diagram. If a current is established in one wire "core" it passes through the coil of the other and drives the second "core" into normal resistivity—the current continuing indefinitely because the energizing coils themselves are held permanently superconductive. Another pair of cryotrons is used to put the flip-flop into the desired state. Other circuits were published in the April, 1956, issue of *Proc.I.R.E.*, where it was stated that a digital computer using cryotrons might be built into a 1-ft cube—excluding the refrigeration plant, of course!

Printed Matrix Store.—The accompanying picture shows the small size of the new RCA storage device based on the magnetic-cell principle which



was described in our February issue (p. 80). The unit stores 2,560 binary digits in a volume of only 2 cubic inches.

Unpublished Reports mentioned above come from various sources but can be obtained from the Technical Information and Documents Unit of the Department of Scientific and Industrial Research, 15, *Regent Street, London, S.W.*1.

LETTERS TO THE EDITOR

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

Colour Television Pitfalls

WHILST agreeing with the spirit of your editorial in the March issue, there are two comments with which I find myself in disagreement: (1) I do not believe it is true to say that the N.T.S.C. system was planned basically for use with the three-gun shadow mask tube, nor is tied to that tube. The system only assumes simultaneous presentation of the red, blue and green components of coloured picture elements and, of course, can be used with several forms of display device (the right one not yet apparently thought of!). (2) The argument for compatibility that "a colour service would be economically impossible . . . unless it were receivable on existing black and white receivers," is, I think, misleading. If the public wished to see the transmissions *in colour* they would have to buy new colour television receivers. The cost of these receivers would be negligibly affected, *whether or not* they were designed to work on a compatible transmission system; i.e., compatibility does not materially affect economy from purely the receiver point of view.

As I see it, economies of compatibility relate almost entirely to the *transmission* side (for which, admittedly, we, as receiver owners, would have to pay indirectly). Apart from the fact that economy of "channel space" is an important consideration (i.e., a compatible system uses existing channels), there is also the fact that existing r.f. outlets—transmitters and aerials—can be used with very little modification. So also can long-distance cable and radio links.

Studio equipment, colour cameras and the like would mean fresh capital expenditure whether the system was compatible or not and would not influence the argument greatly one way or the other.

Having had a good deal of practical field experience of the difficulties with multipath distortion, fading, long-distance interference and other effects on present television and V.H.F. sound reception, I have lately been given to speculating whether it would not be a good idea to confine colour transmission to an almost completely "wired" system (i.e., co-ax run by the G.P.O.!). This would avoid the "ether-space" and many other problems and leave us free to optimize the system, at the same time giving reception free from defects of radiated transmission. Thinly populated areas could be catered for by radiation from Band IV low power relay stations.

Concerning "Cathode Ray's" and "Diallist's" conflicting opinions on the use of "monochrome," I agree with "Cathode Ray" that this is not the best word to use, but I can see nothing wrong with the word *achromatic* which—in the dictionary—is defined as "without colour." (By the way, grey is generally looked upon as achromatic as it is low intensity "white.")

Clacton-on-Sea. D. W. HEIGHTMAN.

Etymological Inexactitude?

IT seems to me that, in their counter-attacks, "Free Grid" and "Diallist" have condemned themselves out of their own pens.

"Diallist" agrees that white is a combination of all the colours of the spectrum, but argues that television "white" is a very pale grey, which he appears to suppose is fundamentally different. If so, I can only refer him to a reliable work on colour. He would have had a better case if he had made use of the fact that many sets' "whites" have a pronounced bluish tinge, but even so the spectral spread is pretty wide.

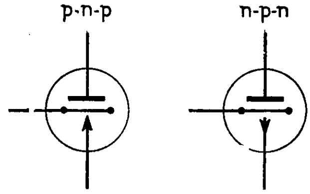
Both he and "Free Grid," whom I had long regarded as sound on etymology, take my breath away with their comments on "panchrome." Did the "fellow with little Latin and less Greek" also compile every reputable English dictionary, from the O.E.D. downwards?

"Free Grid" says he has "by far the stronger case" in asserting that the word "data" is singular. I should advise him to get measured for a larger size in hats, since he appears to know better than such authorities as the "Shorter Oxford English Dictionary," Eric Partridge, Sir Ernest Gowers, and H. W. Fowler.

It should take more than the misguided practice of some of the people in one small branch of knowledge expressed in English to enthrone an upstart solecism as a new accepted usage. "CATHODE RAY."

Transistor Symbols

IN your March issue, James Franklin confessed to an unconscious plagiarism of a transistor symbol that we have used. This we take as flattery. We have recently adopted the "open" type of symbol from the book by Lo, Endres, *et al.* which was mentioned by "Cathode Ray" in your April issue as his personal preference (see accompanying sketch).



National Physical Laboratory, Teddington, Middx. D. L. A. BARBER. W. T. BANE.

Beat Interference

IT is well known that since Winter Hill opened for service on Channel 9, Band III, reception of the Croydon I.T.A. station is often marred by co-channel interference in certain areas. My own observations show that when this interference is visible there is sometimes a pulsating variation of mean brightness level. This may or may not be accompanied by the more usual brightening of groups of lines, giving an impression of line pairing.

When the two stations radiate similar programme material a ghost or ghosts may also appear, depending on the intensity of the Winter Hill signal at this extreme range. When programme material is dissimilar—the "commercials," for example—the ghost(s) give place to two entirely different pictures, one usually weaker than the other.

The pulsating lightening and darkening of the picture experienced here at times is not unlike the conditions related by your contributor in the March issue, James P. Grant. I am therefore led to believe that his trouble could be a form of this co-channel interference. In support of this view, I notice that a line connecting this town with Winter Hill passes through Croydon; similarly, a line from Cawsand and Kingsand to Holme Moss would pass through Hessary Tor.

These two latter stations share Channel 2, Band I, and, I believe, always radiate the same programme material. The trouble, says Mr. Grant, is always present when Hessary Tor is transmitting, but then so is Holme Moss transmitting at those times. He also says there is no recorded signal in the band when Hessary Tor is silent, but again, Holme Moss would also be off the air at those times.

As Mr. Grant seems to have secured the active co-operation of the B.B.C. in investigating his problem, could he not prevail upon them to cut the Holme Moss carrier for a while during a morning or afternoon test transmission period, so that the effect on his reception could be observed. On the assumption that this has not been tried, it might give a lead, if not an answer.

St. Leonards-on-Sea. W. E. THOMPSON.

Peak or R.M.S.?

IN your March issue Thomas G. Ward wonders whether recording equipment makers use peak reading meters for their quoted data.

Partly as the result of pioneer work by Stuart Ballantine, for over twenty years virtually all audio measurements in the U.S.A. have been made by average-reading meters, sine-wave-calibrated in equivalent r.m.s. voltage. This revolution was born of the discovery that amplifier-type average-reading vacuum-tube voltmeters had better linearity and much more sensitivity than the peak-reading type, and infinitely more stability than the r.m.s. vacuum-tube meter. "R.M.S." has become an obsolete cliché.

Today, such average-reading meters are universally used for recording tape and recorder measurement, as well as for virtually all other audio measurements. Since most models are good to several hundred kc/s, and some are accurate up to 4 or 5 Mc/s, they have also seen much r.f. use as well.

Audio Instrument Company, Inc., C. J. LeBEL.
New York, U.S.A.

EXHIBITORS AT THE I.E.A. SHOW

AS its title implies, the Instruments, Electronics and Automation Exhibition (Olympia, May 7th to 17th) will include a considerable amount of equipment of interest to *Wireless World* readers. The show is promoted by five associations, among them the Scientific Instrument Manufacturers' Association and the British Electrical and Allied Manufacturers' Association. Although officially the radio and electronics industry is not represented, there are among the 200 exhibitors a considerable number (see below) of manufacturers in the industry, or whose products are used extensively in the manufacture of radio and electronic equipment.

A conference will be run in conjunction with the exhibition, for which tickets will be obtainable at the show. Each day will be devoted to a specific aspect of the industries covered by the exhibition—automation (8th), nuclear (9th), education (10th), medical (13th), industrial (14th), computer (15th), communications and navigation (16th). The morning session (from 11.0) will be devoted to a general review of the day's subject, whilst more specific techniques and applications will be covered in the afternoon session (from 3.0) Some of the papers are listed below.

The exhibition opens daily (except Sunday) at 10.0, and closes at 6.0 except on the 10th and 15th, when it is open until 9.0. Admission, 2s 6d.

Name	Stand No.
Advance Components	934
Aircraft-Marine Products	936
Airmec	408
Associated Automation	510
Automatic Coil Winder (AVO)	942A
B.T.H.	309
Baird & Tatlock	515
Baldwin Instrument Co.	933
Belling & Lee	938
Bonochord	711
British Physical Laboratories	205
Brown, S. G.	704
Cambridge Instrument Co.	601
Casella (Electronics)	412
Cass & Phillip	945
Cathodeon	501
Cawkell, A. E.	716
Cinema-Television	913
Cooke, Troughton & Simms	806
Cossor	407
Crompton Parkinson	408
Croydon Precision Inst. Co.	947
D.S.I.R.	502
Dawe Instruments	939
De La Rue	209
Donvin Instruments	925
Dubilier	908
Ekco Electronics	505
Elcontrol	918
Electro Methods	904
Electroflo Meters Co.	510
Electronic Engineering	206
Electronic Instruments	930
Electrothermal Engineering	300
Elliott Brothers	411
E.M.I. Electronics	404
English Electric Valve Co.	107
Ericsson Telephones	613
Evans Electroselenium	200
Evershed & Vignoles	405
Fleming Radio	103A
Foxboro-Yoxall	409
G.E.C.	406
General Radiological	703
Hilger & Watts	402
Honeywell-Brown	410
Hunt (Capacitors)	922
Kelvin & Hughes	310
Labgear	501
Lancashire Dynamo Electronic Products	303
Langley	914
Livingston Laboratories	600
Magnetic Devices	706
Mallory Batteries	944
Marconi Instruments	504
Measuring Instruments (Pullin)	925
Metropolitan-Vickers	401
Microcell	707
Millett Levens	921
Minerva Detector Co.	930
Ministry of Supply	909
Morganite Resistors	927
Muirhead	901
Mullard	305 & 801
Murphy Radio	703
N.S.F.	919
Nagard	216
Nalder Bros. & Thompson	603
Nash & Thompson	105
National Cash Register Co.	311
Nicholson, W. B. (Scientific Inst.)	515
Painton & Co.	211
Philips Electrical	910
Plannair	604
Power Controls	706
Pullin, R. B. & Co.	925
Pye, W. G. & Co.	501
Racal Engineering	932
Radiovisor Parent	923
Robinson, F. C. & Partners	212
S.T.C.	307
Servomex Controls	900
Short Brothers & Harland	106
Siemens-Ediswan	507
Sifam Electrical Instrument Co.	808
Simmonds Aerocessories	903
Smiths Industrial Instruments	929
Society of Instrument Technology	101
Solartron	503
Southern Instruments	100
Sperry Gyroscope Co.	203
Sunvic Controls	506
T.C.C.	602
Telephone Manufacturing Co.	201
Turner Electrical Instruments	937
20th Century Electronics	946
Unicam Instruments	501
Victoria Instruments	925
Wayne Kerr Laboratories	304
Wireless World and *Electronic & Radio Engineer*	941

Some Conference Papers

8th. "Computer controlled machine tools" by J. N. Toothill (Ferranti). "Electronically controlled machine tools" by C. A. Sparkes (H. W. Kearns & Co.).

9th. "The place of analogue computers in reactor control" by J. Walker (Atomic Energy Authority).

10th. "The technologist—his training and reward" by Dr. G. L. D'Ombrain (Battersea Polytechnic). "Training for research" by Dr. J. Thompson (Scientific Instrument Research Association).

13th. "Electronic instruments for clinical tests with radioactive isotopes" by N. Veall (Guy's Hospital) and E. W. Pulsford (Atomic Energy Authority).

14th. "Instrumentation in the textile industries" by J. E. Fielden (Fielden Research).

15th. "The electronic office" by Sir Walter Puckey. "Production control procedures using a computer" by J. W. Grant (British Tabulating Machine Co.). "Electronics in banking" by L. Temple (Lloyds Bank).

16th. "Communications and the future" by Sir Gordon Radley. "Recent developments in marine radar" by A. L. P. Milwright (Royal Naval Scientific Service). "Air navigation" by T. G. Thorne (Radar Research Establishment).

Limiters and Discriminators for F.M. Receivers

3 (cont'd)—Practical Ratio Detector Circuits: Comparison of Foster-Seeley and Ratio Detectors

By G. G. JOHNSTONE, B.Sc.*

To extend the treatment to a practical ratio detector we shall next consider the case when the parallel resistance of the tuned secondary circuit R_s is not infinite.

As before, the fundamental-frequency currents (I_{ac}) flowing through the diodes are equal in magnitude, and the current in each diode is in phase with its applied voltage. Additionally, the current flowing through the resistive components $R_s/2$ are also in phase with the applied voltage. These currents are given by $2E_1/R_s$ and $2E_2/R_s$ respectively. The equations relating the magnitude of the currents flowing must thus be modified as follows:

$$(I/2)^2 = E_1^2Y_1^2 + (I_{ac} + 2E_1/R_s)^2$$
$$(I/2)^2 = E_2^2Y_2^2 + (I_{ac} + 2E_2/R_s)^2$$

where Y_1 and Y_2 have the same meaning as formerly, i.e. they are the admittances of the reactive elements of the tuned circuits. Inserting the values for Y_1 and Y_2 and writing $g_s = 1/R_s$

$$E_1^2\,[4C_s(\Delta\omega - \Delta\Omega)]^2 - E_2[4C_s(\Delta\omega + \Delta\Omega)]^2 + 4I_{ac}\,g_s(E_1 - E_2) + 4g_s^2(E_1^2 - E_2^2) = 0$$

As the diode rectification efficiency is assumed 100 per cent, $E_1 = E_b + E$ and $E_2 = E_b - E$, where E is the a.f. output voltage.

Combining the expressions above gives

$$\frac{E}{E_b} = \frac{-\Delta\omega}{\Delta\Omega} \times \frac{1 + (E/E_b)^2}{1+(g_s^2/4C_s^2\Delta\Omega^2)+I_{ac}g_s/(8C_s^2\Delta\Omega^2E_b)+(\Delta\omega/\Omega\Delta)^2}$$

In this expression, we can replace I_{ac} by $2I_{dc}$, and we can simplify the expression appreciably for initial examination by restricting consideration to the region where $\Delta\omega/\Delta\Omega$ is appreciably less than unity, i.e. to the working region near the centre frequency. The expression for E then becomes

$$E = -E_b\frac{\Delta\omega}{\Delta\Omega} \times \frac{1}{1+g_s^2/(4C_s^2\Delta\Omega^2)+g_sI_{dc}/(4C_s^2\Delta\Omega^2E_b)}$$

To a first degree of approximation therefore, the output is linearly proportional to the frequency of the input signal. However, it can be shown analytically that if the input current (I) increases, then so does the direct current in the load, I_{dc}. This is apparent also from an inspection of the circuit. Thus we can draw the important conclusion that the audio output voltage *decreases*, as the input current *increases*, and conversely. In this form the circuit is over-compensated. An examination of the expression above suggests a way out of this difficulty. If only part of the load voltage is "stabilized," i.e. shunted by a large capacitor, E_b will be no longer constant, and variations of numerator and denominator may be made to cancel. If a resistor R_m is inserted in series with each "battery" as shown in Fig. 10, R_L becomes $R_m + R'_L$, where R_L' is the resistance shunted by the large-value capacitor. E_b in the foregoing expressions must then be replaced by $E_b' + R_mI_{dc}$, where E_b' is the new battery voltage, i.e. that developed across R_L', no longer equal to the total load voltage. Inserting this value for E_b' in the expression above gives

$$E = -E_b'\frac{\Delta\omega}{\Delta\Omega} \times \frac{1 + R_m\,I_{dc}/E_b'}{(1 + g_s^2/4C_s^2\Delta\Omega^2)\;\;[1 + g_sI_{dc}/(g_s^2 + 4C_s^2\Delta\Omega^2)E_b]}$$

The factor $1/E_b$ is the denominator can also be replaced by $1/E_b'(1+R_mI_{dc}/E'_b)$, and provided the voltage R_mI_{dc} is small compared with E_b', this can then be replaced by the first two terms of the series expansion, viz.

$$\frac{1}{E_b'(1 + R_mI_{dc}/E_b')} = \frac{1}{E_b'}(1 - R_mI_{dc}/E_b')$$

Then

$$E = \frac{-E_b'(1 + R_mI_{dc}/E_b')\,(\Delta\omega/\Delta\Omega)}{\{1 + g_s^2/4C_s^2\Delta\Omega^2\}\left[1 + \dfrac{g_sI_{dc}(1 - R_mI_{dc}/E_b')}{E_b'\,(g_s^2 + 4C_s^2\Delta\Omega^2)}\right]}$$

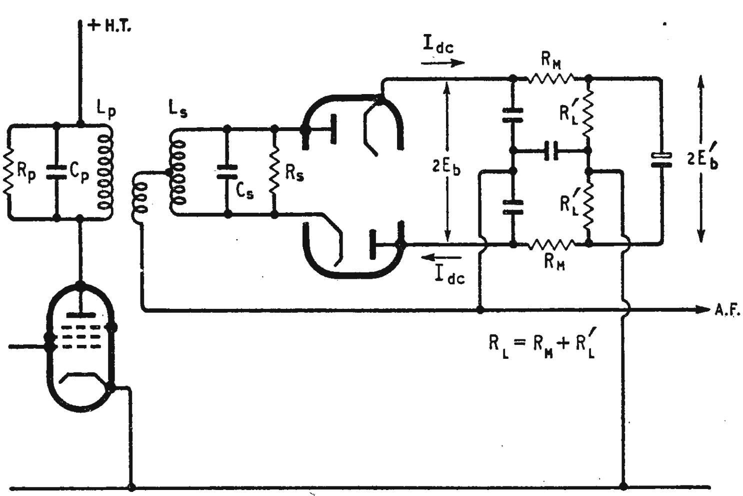


Fig. 10. Ratio detector with resistors R_m to improve a.m. suppression.

* B.B.C. Engineering Training Department.

The output E is independent of I_{dc} to a good degree of approximation if

$$R_m = g_s(1 - R_m I_{dc}/E_b') / (g_s^2 + 4C_s^2 \Delta\Omega^2)$$

$$\text{i.e. } R_m = \frac{g_s}{g_s^2+4C_s^2\Delta\Omega^2} \cdot \frac{1}{1+g_s I_{dc}/\{E_b'(g_s^2+4C_s^2\Delta\Omega^2)\}}$$

$$= \frac{g_s}{g_s^2 + 4C_s^2\Delta\Omega^2 + g_s I_{dc}/E_b'}$$

This expression can be simplified by introducing the undamped Q value of the secondary circuit $Q_s = R_s\omega_o C_s = \omega_o C_s/g_s$. Then

$$R_m = R_s/\{1 + (2Q_s \Delta F/f_o)^2 + R_s I_{dc}/E_b'\}$$

This expression shows that complete a.m. rejection cannot be achieved, since the optimum value of R_m depends on I_{dc}, which varies during the a.m. cycle. We can make the output due to a.m. zero over a limited range about a selected value of I_{dc}. It is usual to do this about the working point, when E_b'/I_{dc} is equal to R_L', the resistance in parallel with the stabilizing capacitor. Then

$$R_m = R_{m\,opt} = R_s/\{1 + (2Q_s\Delta F/f_o)^2 + R_s/R_L'\}$$

The effect of varying R_m whilst the total diode load remains constant is shown in Fig. 11, which shows how the output varies with an a.m. input when the signal frequency is constant at a value near the centre frequency. The value of R_m is expressed in terms of $U = R_m/R_L$, where $R_L = R_L' + R_m$. The factor U is equal to the fraction of the output voltage which is not stabilized. The optimum value of U corresponding to $R_{m\,opt}$ calculated above is designated U_{opt}.

At this point it is convenient to introduce the "a.m. suppression ratio." This is a measure of the effectiveness of a f.m. detector in rejecting a.m. of the input signal. It is the ratio of the a.f. output due to f.m. to that due to a.m. when the input signal is modulated equally in depth by a.m. and f.m. The value of modulation depth employed is usually

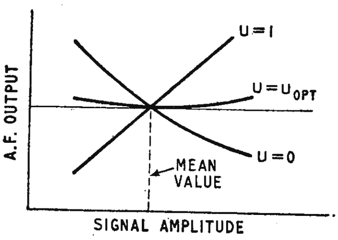


Fig. 11. Showing variation of a.f. output with input signal amplitude for a fixed frequency input signal (Δf small).

30 or 40 per cent. Different frequencies are usually employed for the a.m. and f.m. components to facilitate measurement. Typical values for these frequencies are 100 c/s for the f.m. component, and 2 kc/s for the a.m. component. In a practical ratio detector the a.m. suppression ratio is between 20 and 30 db.

If now we return to the full expression derived earlier for E the a.f. output voltage, we can evaluate the distortion terms in the output. Substituting for the value of E_b leads to the following expression for the a.f. output voltage E expressed as a fraction of E_b'

$$y = -Ax\frac{1 + B^2y^2}{1 + ABx^2}$$

where $y = E/E_b'$

$x = \Delta\omega/\Delta\Omega = \Delta f/\Delta F$

$A = (2Q_s\Delta F/f_o)^2/\{1 + (2Q_s\,\Delta F/f_o)^2\}$

$B = R_L'/(R_L' + R_m)$. This is the fraction of the direct voltage at the diode output "stabilized" by the electrolytic capacitor, and is equal to E_b'/E_b.

If the graph of y against x is plotted, it has the form shown in Fig. 12 for the portion of the curve in which we are interested.

The expression for y can be expanded as a power series, giving

$y = E/E_b' = d_1(\Delta f/\Delta F) + d_3(\Delta f/\Delta F)^3 \ldots\ldots$

where $d_1 = -A$

and $d_3 = A^2B(1 - AB)$

In order to use this expression to determine distortion terms, the value of ΔF must be known. Except for the special case of R_s infinite, this is not equal to the half-bandwidth (ΔF_p) measured to the turn-over point of the practical characteristic. However, in the process of deriving the expansion above, it emerges that the turn-over points of the characteristics occur at the values given by $x_p^2 = 1/AB$. As A and B are both less than unity, the measured half-bandwidth ΔF_p is greater than ΔF. In a practical circuit, if the measured half-bandwidth is found, ΔF can be found from

$$\Delta F = \Delta F_p\sqrt{AB}$$

The value of B can be calculated from the circuit constants. The value of A depends up ΔF, and hence requires a knowledge of the answer. However, ΔF can be found by successive approximations if the value of ΔF_p is used instead of ΔF to calculate A. This gives an approximate value of ΔF, which can be used to determine A more accurately, and so on. In fact, the error introduced by using the first approximation only is generally small.

Alternatively, the value of ΔF can be calculated from a knowledge of circuit values. Thus the resonance frequencies of the two tuned circuits are given by $1/2\pi\sqrt{(1 + M/2L_p)L_sC_s}$ and $1/2\pi\sqrt{(1-M/2L_p)L_sC_s}$ respectively. From these expressions $\Delta F/f_o = M/4L_p$, whence

$$\Delta F = Mf_o/4L_p$$

If a tertiary winding or tapped primary circuit is employed, then L_p must be replaced by a^2L_p, and M by aM, giving

$$\Delta F = Mf_o/4aL_p$$

The expression for the output voltage is given in terms of E_b' and ΔF. If it is required to determine the sensitivity of the circuit, we require an expression relating E_b' to I_{in}. With a tertiary winding or tapped primary circuit, the equivalent circuit must be drawn with L_p replaced by a^2L_p, C_p by C_p/a^2, R_p by a^2R_p and I_{in} by I_{in}/a. We shall consider the signal frequency to be near the centre frequency. We can then ignore the effect of the reactive components of the tuned circuit connected between terminals 1 and 2 of the equivalent circuit. The dynamic resistance of this tuned circuit (R′) is that which in parallel with $R_s/4$ is equal to a^2R_p (see Part 1), i.e.

$$\frac{1}{R'} + \frac{4}{R_s} = \frac{1}{a^2R_p}$$

The impedance presented at the centre tap of the transformer T by the two tuned circuits and diode loads can be shown by an extension of the argument employed earlier to be

$$R_1 = \left(\frac{R_D}{4}\right) \Big/ \{1 + (2Q_w\,\Delta F/f_o)^2\}$$

where $R_D/2$ is equal to $R_L/2$ in parallel with $R_s/2$, i.e. the total damping applied to each of the two tuned circuits considered previously. The current flowing

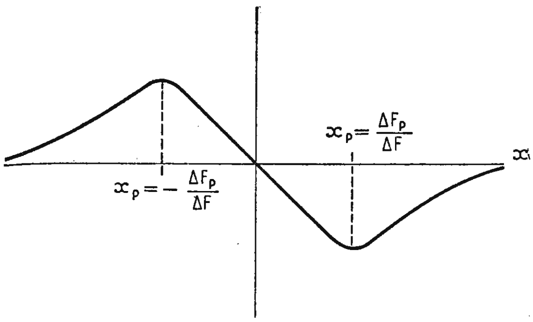


Fig. 12. Showing variations of output ($y = E/E_b'$) against input signal frequency ($x = \Delta f/\Delta F$).

to the centre tap of the transformer T is then given by

$$I = \frac{I_{in}}{a}\,\frac{R'}{R_1 + R'}$$

The power delivered to the centre tap of the transformer is thus

$$P_{in} = \tfrac{1}{2}I^2R_1$$
$$= \tfrac{1}{2}\left(\frac{I_{in}}{a}\,\frac{R'}{R_1+R'}\right)^2 R_1$$

This power appears in the diode load circuit and in the dynamic resistances ($R_s/2$) of the two tuned circuits. Near the centre frequency, the voltage across each dynamic resistance is approximately E_b, and hence the power dissipated in each resistance is $\tfrac{1}{2}E_b^2/(R_s/2)$. The power in each diode load is E_b^2/R_L, and hence

$$\frac{2E_b^2}{R_L} + \frac{2E_b^2}{R_s} = \tfrac{1}{2}\frac{I_{in}^2}{a^2}\,\frac{R'^2}{(R_1 + R')^2}\,R_1$$

But $$\frac{2}{R_L} + \frac{2}{R_s} = \frac{2}{R_D}$$

$$E_b^2 = \tfrac{1}{4}\frac{I_{in}^2}{a^2}\,\frac{R'^2}{(R_1 + R')^2}\,R_1R_D$$

$$E_b = \tfrac{1}{2}\frac{I_{in}}{a}\,\frac{R'}{R_1 + R'}\,\sqrt{R_1R_D}$$

This expression has its maximum value when $a = a_{opt}$; this value of a is given by

$$1/a^2_{opt} = R_p\{1/R_1 - 4/R_s\}$$

Using this value for a, and $E_b' = E_bR_L'/R_L$, gives the maximum value for $E_b' = E_{b'max}$

$$E_{b'max} = \tfrac{1}{4}\frac{R_L'}{R_L}\,I_{in}\,\sqrt{R_pR_D/\{1 - (4R_1/R_s)\}}$$

If as is usual, $R_s/4$ appreciably greater than R_1 then

$$E_{b'max} \approx \tfrac{1}{4}\frac{R_L'}{R_L}\,I_{in}\sqrt{R_pR_D}$$

and $$a^2_{opt} \approx R_1/R_p$$

Near the centre frequency, the a.f. output voltage is given approximately by

$$E = -AE_b'\Delta f/\Delta F$$

For maximum sensitivity, E_b' should be large and ΔF small. For E_b' to be large R_p and R_D should be large. However, as we shall show next, the condition for good "downward" a.m. handling capacity requires R_D small. Thus a practical design represents a compromise between these requirements.

To complete the investigation of the circuit, we shall evaluate the maximum "downward" a.m. handling capacity. With no a.m. present, the relationship between the peak value of the r.f. input current to each of the tuned circuits ($I/2$), when the signal frequency is near the centre frequency, is given by

$$(I/2)^2 = E_b^2(16C_s^2\Delta\Omega^2 + 4/R_D^2)$$
$$= E_b^2 16C_s^2\Delta\Omega^2\{1 + 1/(2Q_w\Delta F/f_o)^2\}$$

When the diode current falls to zero, the value of the r.f. input current ($I'/2$) is given by

$$(I'/2)^2 = E_b'^2\ 16C_s\ \Delta\Omega^2\{1 + 1/(2Q_s\Delta F/f_o)^2\}$$

whence

$$m_{max} = 1 - I'/I = 1 - \frac{E_b'}{E_b}\sqrt{\frac{1+1/(2Q_s\ \Delta F/f_o)^2}{1+1/(2Q_w\Delta F/f_o)^2}}$$

$$= 1 - \frac{R_L'}{R_L}\sqrt{\frac{1 + 1/(2Q_s\ \Delta\ F/f_o)^2}{1 + 1/(2Q_w\Delta F/f_o)^2}}$$

If $2Q_s\ \Delta F/f_o$ is large, the expression simplifies to one similar to that given earlier for the case of R_s infinite.

The value of m_{max} calculated above ignores the effect of the primary circuit, and in general this is not negligible. To evaluate this, consider the input impedance presented at the centre tap of the transformer T of the equivalent circuit. With no a.m. present, this is

$$R_1 = (R_D/4)/\{1 + 2Q_w\ \Delta F/f_o)^2$$

Similarly, the impedance when the diode current falls to zero is

$$R_2 = (R_s/4)/\{1 + (2Q_s\Delta\ F/f_o)^2\}$$

If the values of R_1 and R_2 differ, then m_{max} is modified. This happens because the proportion of the input current (I_{in}/a) fed to the centre tap of the transformer T differs in the two cases. The effective impedance R' of the current source was shown earlier to be

$$1/R' = 1/a^2R_p - 4/R_s$$

Thus the proportion of the input current flowing to the centre tap when no a.m. is present is given by

$$I = \frac{I_{in}}{a}\,\frac{R'}{R_1 + R'}$$

and when the diode current falls to zero by

$$I' = \frac{I_{in}'}{a}\,\frac{R'}{R_2 + R'}$$

Thus m_{max} is changed from the value calculated above to

$$m'_{max} = 1 - \frac{I_{in}'}{I_{in}} = 1 - \frac{I'}{I}\,\frac{R'+R_2}{R'+R_1}$$

$$= 1 - \frac{R' + R_2}{R' + R_1}\,\frac{R_L'}{R_L}\sqrt{\frac{1+1/(2Q_s\Delta\ F/f_o)^2}{1+1/(2Q_w\Delta F/f_o)^2}}$$

Ratio Detector with Practical Diodes.—The analysis of the circuit operation with practical diodes, i.e. those with a rectification efficiency of less than 100 per cent is very complex, because the direct current component in the diode I_{dc} is no longer equal to half the peak value of the fundamental frequency a.c. component I_{ac}. If the diode efficiency is high, however, the assumption that $I_{dc} = \tfrac{1}{2}I_{ac}$ may still be made with fair accuracy. The diode itself must then be regarded as a perfect diode in series with a resistor R_{di}. This resistance then forms part of the resistance R_m calculated earlier, and represents a minimum value below which R_m cannot fall. To calculate its value, we may note that given an input peak voltage E the "perfect" diode delivers an output voltage E. A fraction of this voltage, ηE, appears across the true load resistance R_L, where η is the diode rectification efficiency.

The remainder of the voltage $(1-\eta)$ E, appears across the fictitious resistor R_{di}. Hence

$$\eta \frac{E}{R_L} = \frac{1-\eta}{R_{di}} \cdot E$$

$$R_{di} = \frac{1-\eta}{\eta} R_L$$

It is the fact that η varies with the input signal level which limits the useful range of input signal levels which the detector can handle satisfactorily.

Normally, η tends to a constant value as the input signal increases, and the circuit constants are adjusted for this value of η. At low input signal levels, however, η decreases appreciably, and the a.m. suppression ratio is seriously impaired. Thus there is a lower limit of input signal which the detector can handle satisfactorily. It is apparent that, for best performance high-efficiency diodes should be employed.

Unbalanced Effects.—In the presence of amplitude modulation, a ratio detector exhibits an "unbalance effect." This is an output due to the a.m. which is constant at all frequencies in the working range. This effect has a number of causes, which are not indicated by the preceding anaysis because of the simplifying assumptions made. The causes include variations of diode input capacitance with signal amplitude, the finite impedance of the tuned circuits to harmonics of the current flowing in the diodes, and inadequate decoupling of the diode loads at r.f. The last cause produces an effect which opposes that due to the first, and hence some reduction of the a.m. output may be obtained by using relatively small decoupling capacitors. The second cause can be minimized by using a large value of secondary circuit tuning capacitance. This tends to produce low values of R_s, the dynamic resistance, and hence tends to lead to low sensitivity. A compromise is thus necessary, and a value of 50pF is usually employed. The a.m. output can, however, most easily be reduced by unbalancing the two diode-load circuit resistors, R_m. The foregoing analysis suggests that these should be equal; if, however, their sum is kept constant, while they are altered individually, substantial reduction of the a.m. output is then obtained.

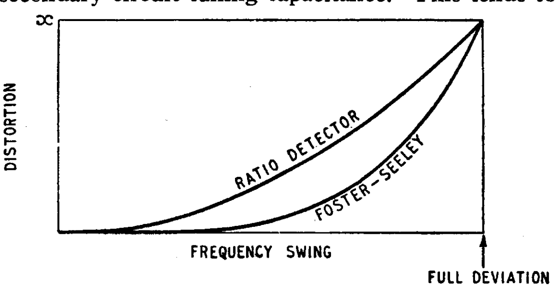


Fig. 13. Showing how distortion varies for ratio detector and Foster-Seeley circuits having equal distortion at full deviation.

Time Constant of Load Circuit.—The foregoing analysis was based upon the assumption that the time constant of the load circuit was very large, so that the load circuit could be replaced by a battery for the purposes of analysis. Unfortunately, if the time constant of the circuit is made very large, the tuning characteristics of the receiver are affected. The receiver then behaves like a conventional a.m. receiver in which the a.g.c. time constant is too long; there is an appreciable lag between adjustment of the tuning control and the return to stable operating conditions. The tuning has then to be adjusted very slowly. To avoid this effect, the load time-constant has to be shorter than is desirable. In practice a compromise value of time constant of the order of 0.1 to 0.2 seconds is usually employed. Such a circuit ceases to behave like a constant-voltage battery when the input is varying at a slow rate, and there is a slow variation of the output signal in accordance with the signal variation. This is especially noticeable if "flutter" due to signal reflections from an aircraft occurs. This flutter generally begins to be noticeable when the flutter rate is about 0.5 c/s; the flutter rate increases, as does also the amplitude of the "flutter," until the flutter rate rises to value when the load time-constant is sufficient to suppress the variations. To counter this effect, an effective fast-acting a.g.c. system is required. A suitable control voltage is available from the load circuit itself, and this is usually employed. The a.g.c. system also has the desirable effect of equalizing the audio output from input signals of unequal amplitude.

Variants of the Ratio Detector Circuit.—A number of variants of the ratio detector circuit have been described from time to time. The most common of these employ two tuned circuits instead of the phase-difference transformer. Two such circuits, shown in Figs. 14 and 15, are described by Paananen. In the circuit of Fig. 14, two tuned circuits are driven from two valves with the input grids connected in parallel, to supply equal currents to the tuned circuits. A battery is employed instead of the self-biasing circuit. In the circuit of Fig. 15, a low impedance source (a cathode follower) is used to drive two series-tuned circuits; the "battery" voltage is provided by the cathode bias of the cathode follower. This circuit may be described as the dual of that of Fig. 14, in that a constant voltage is fed to two series-tuned circuits instead of a constant current to two parallel-tuned circuits.

Comparison of the Foster-Seeley and Ratio Detector Circuits

A comparison of these two circuits depends critically upon the requirements of the detector in a receiver. These may be stated as (a) low distortion (b) good "downward" a.m. handling capacity (c) good a.m. suppression ratio (d) driving voltage required and (e) wide-band characteristics. On the score of low distortion, the Foster-Seeley circuit is better than a ratio detector of comparable bandwidth, although not necessarily better than a wide-band ratio detector.

The two circuits differ appreciably in the way in which the distortion varies with the signal frequency swing. In the Foster-Seeley circuit, the distortion at optimum adjustment increases with the fourth power of the swing; in the ratio detector it increases with the square of the swing. Thus if both circuits are adjusted to give equal amounts of third-harmonic distortion at full deviation, their characteristics at smaller frequency swings will be different. This is shown in Fig. 13.

In respect of "downward" a.m. handling capacity, the two are not strictly comparable, since in the Foster-Seeley circuit this maximum "downward"

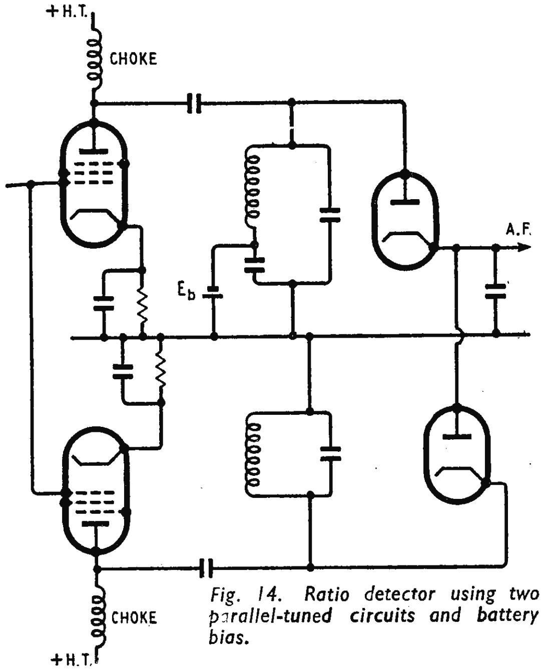


Fig. 14. Ratio detector using two parallel-tuned circuits and battery bias.

a.m. handling capacity is proportional to the amount by which the input signal exceeds the " threshold " input required by the limiter. In the ratio detector, the maximum " downward " a.m. handling capacity is a fixed quantity. In general a detector should be capable of handling " downward " modulation of the order of 50 per cent, and both circuits can normally achieve this.

The a.m. suppression ratio required in a receiver depends upon the type of interference encountered. To deal satisfactorily with all types of interference a ratio of 35–40 dB would appear to be necessary. The Foster-Seeley circuit preceded by a limiter has a ratio of the order of 40 dB. The ratio detector, in practice, appears to have a ratio of the order of 20–30 dB. This is not sufficient for all types of interference, and is perhaps the most serious limitation of the circuit. The ratio can be increased by employing a limiter preceding the detector, but if this is done a relatively large input signal to the stage is required. This offsets one of the major attractions of the ratio detector, the smaller number of valves required in a receiver. A hybrid arrangement, in which the preceding valve functions as a high-level limiter, may go some way to improving performance, but there may be difficulties in areas of low field strength. Alternatively, a diode dynamic limiter may be added to increase the a.m. suppression ratio, but this generally leads to some loss of overall gain.

The driving voltage quoted differs for the two cases. With a Foster-Seeley circuit, there is a " threshold " at which the limiter commences to function satisfactorily. Below this threshold the a.m. suppression ratio is poor, the " downward " a.m. handling capacity zero, and the a.f. output varies approximately linearly with the input signal amplitude. Above the threshold, the a.m. suppression ratio rises rapidly to an approximately constant value, and the a.f. output tends to a constant value. The " downward " a.m. handling capacity rises linearly with the ratio of input signal amplitude to threshold amplitude. In a ratio detector there is a "threshold" of a different type. This occurs when the input signal falls to the point where the diode efficiency begins to fall off. Below this threshold the a.m. suppression ratio and " downward " a.m. handling capacity decrease steadily. Above this threshold the a.m. suppression ratio and the " downward " a.m. handling capacity tend to constant values. The a.f. output, however, is proportional to input signal mean amplitude at all amplitudes except below the " threshold " where it falls somewhat more rapidly than the input signal mean amplitude.

The minimum input signal for satisfactory operation with a Foster-Seeley circuit is thus fairly well defined. If the circuit is to handle " downward " a.m. to a modulation depth of 50 per cent, this requires the input signal to the limiter to be approximately twice the threshold input. In a practical circuit, this corresponds to an input signal of some two volts at the limiter grid. The " threshold " input signal with a ratio detector is usually stated as the input voltage required at the grid of the i.f. stage feeding the detector, and this may be of the order of 20 mV. At this figure, however, the a.f. output may be appreciably below that of the Foster-Seeley circuit, and as a basis of comparison the ratio detector driver input, for an output comparable to that of a Foster-Seeley circuit, is perhaps better. A typical practical figure for the ratio detector on this basis of comparison is some 100 mV, the a.f. output being then approximately 1 volt peak. The overall gain from the aerial input to the driver/limiter grid is thus less by a factor of approximately 20 in a receiver employing a ratio detector than that in a receiver employing a Foster-Seeley circuit, and may enable an i.f. stage to be omitted. However, this saving may not be possible if the a.m. suppression ratio of the ratio detector has to be supplemented.

If a wide-band detector is required, the ratio detector would appear to be most satisfactory. It was stated in Part 2 that the Foster-Seeley circuit may suffer from " diagonal clipping," which occurs if the time-constants of the diode loads are so great that the envelopes of the signals applied to the diodes can fall faster than the rectified output falls. With increasing bandwidth the input signal envelope can fall progressively more rapidly and hence with a Foster-Seeley circuit, the diode loads must be reduced progressively with increased bandwidth. This leads to appreciable design difficulties. The ratio detector, however, can be made free from " diagonal clipping " as in the circuits of Figs. 14

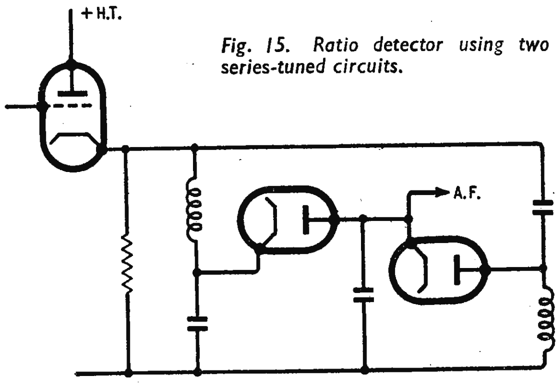


Fig. 15. Ratio detector using two series-tuned circuits.

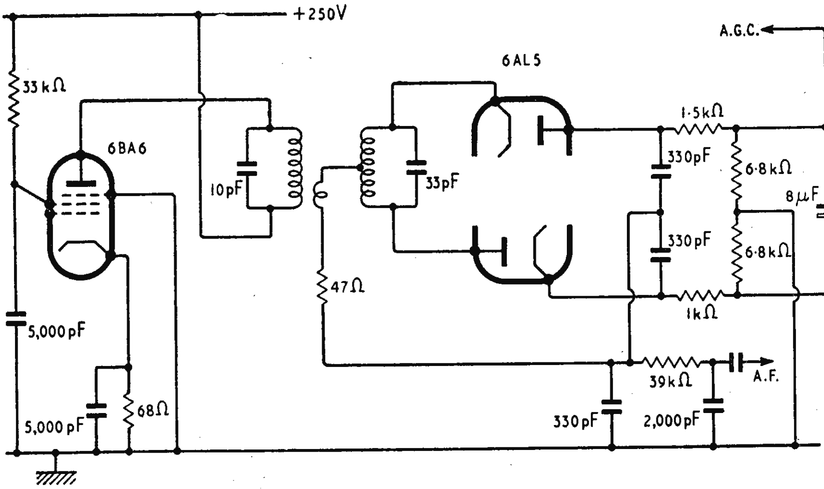


Fig. 16. Circuit values used in ratio detector described by Seeley and Avins (RCA Review, *June 1947*).

equal to E_b'. Assuming the 6BA6 to have a mutual conductance of 4.3 mA/V, the calculated value of E_b' is 2.3 volts. The measured value of the maximum "downward" a.m. capacity is 70 per cent; the calculated value is 70 per cent also.

To evaluate sensitivity and distortion, the values of A and B are required. From circuit values B = 0.68. The value of A is calculated to be 0.83, given the measured half-bandwidth (ΔF_p) of 175 kc/s. The value of ΔF is then 135 kc/s approximately.

Taking E_b' as 2.5 volts, the a.f. output voltage is given by $E = 0.0154(\Delta f) + 2.7 \times 10^{-7}(\Delta f)^3 \ldots$

where Δf is measured in kc/s.

With an input signal of 75 kc/s deviation, i.e., $\Delta f = 75 \cos \omega t$

$$E = 1.06 \cos \omega t + 0.03 \cos 3\ \omega t \ldots$$

The calculated r.m.s. fundamental frequency a.f. output is 0.75 volt; the measured value is 0.7 volt. The calculated third harmonic distortion is 2.0 per cent (r.m.s.); the measured total harmonic distortion is 2.5 per cent (r.m.s.).

and 15. With increased bandwidth, the "downward" a.m. handling capacity decreases, and hence a wide-band ratio detector must be preceded by an efficient limiter.

Theoretical and Practical Results

To illustrate the order of accuracy of the preceding analysis, the practical results can be compared with those given for a published design. The design chosen is that due to Seeley and Avins, described in the *RCA Review*, June 1947. The circuit diagram is shown in Fig. 16.

The rectification efficiency of the diodes was estimated from published data to be 0.8 approximately. The value of R_{di}, the equivalent inherent resistance of each diode, is thus found to be 2 kΩ. This gives the mean value of R_m of the practical circuit as 3.25 kΩ. The calculated value is 3.2 kΩ.

The measured a.g.c. voltage is 2.5 volts for an r.f. input of 100 mV to the grid of the 6BA6. This is

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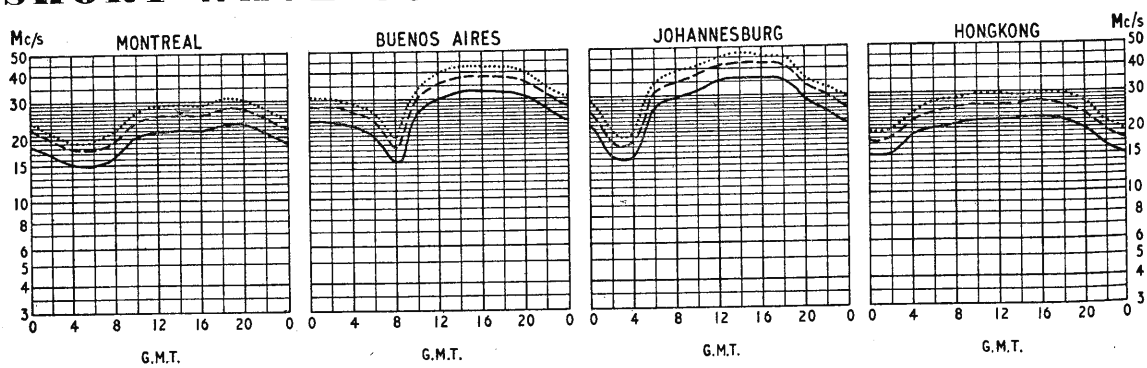
SHORT-WAVE CONDITIONS

Prediction for May



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

— — — PREDICTED AVERAGE MAXIMUM USABLE FREQUENCY

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

THE full 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.

Portable Transistor Receiver

By ***S. W. AMOS****, *B.Sc. (Hons.), A.M.I.E.E.*

SENSITIVE SUPERHETERODYNE CIRCUIT INCORPORATING R.F. TRANSISTORS

I. GENERAL PRINCIPLES OF DESIGN

THE junction transistors which have been available in this country for a few years have been mainly a.f. types with alpha cut-off frequencies not exceeding 0.5 Mc/s. Though perfectly suitable for use in audio amplifiers, these are far from ideal for use in r.f. or i.f. amplifiers or as frequency changers and it has not therefore been possible to construct satisfactory superheterodyne receivers using such transistors in all stages. A number of circuits for transistor superhets have been published but these have relied on the use of low intermediate frequencies such as 315 kc/s, and/or oscillators which operate below the signal frequency. Low intermediate frequencies increase the danger of image interference and low oscillator frequencies make ganging of oscillator with signal-frequency circuits difficult.

The alpha cut-off frequency quoted by transistor manufacturers is the frequency at which the current gain of the transistor, when used as a common-base amplifier, is 3 dB down compared with the low-frequency gain. However, for a satisfactory performance from a common-base amplifier the alpha cut-off frequency must be at least twice the operating frequency: thus if the intermediate frequency is 465 kc/s an alpha cut-off frequency of at least 1 Mc/s is required. For reasons given later common-emitter operation is generally preferred, and for satisfactory performance in this mode the alpha cut-off frequency must be higher still. Thus transistors intended for use in i.f. stages usually have alpha cut-off frequencies in the range 1 Mc/s to 5 Mc/s. The requirements of the frequency changer are even more stringent because the transistor used in this position must be capable of oscillating at 2 Mc/s when the receiver is tuned to the high-frequency end of the medium waveband: transistors intended for such applications may have alpha cut-off frequencies as high as 8 Mc/s. Recently transistors of this type—known as r.f. transistors—have been introduced. With them it is now possible, for the first time, to construct a superheterodyne receiver with transistors in all stages which will operate over the full medium waveband (550 kc/s to 1.6 Mc/s) using the conventional intermediate frequency of 465 kc/s.

Low Running Costs

This article describes the design of a portable battery-operated receiver of this type using a total of seven junction transistors (four a.f. types and three r.f. types) and one point-contact diode. The power output is more than 300 mW and the sensitivity is such that, even with a ferrite-rod aerial, the output stage can be overloaded on Brussels and Hilversum when the receiver is used in the London area. The receiver operates from a 4.5- or 6-volt battery. Such a receiver offers a number of advantages over the conventional portable 4-valve battery-operated superhet and it is interesting to compare the two receivers. Perhaps the most outstanding difference between them is in efficiency, i.e., the ratio of the power delivered to the loudspeaker to the power taken from the batteries. For the transistor set this approaches 60 per cent at maximum volume, nearly six times the maximum likely to be obtained from the most economical valve receiver. As a result the transistor set is more economical to operate. For example, the receiver to be described takes an average current of 25 mA and 6 volts and a type PP1 battery costing three shillings has a life of 150 hours when discharged for four hours per day. The running cost is thus less than one farthing per hour and if larger batteries are used it is even less. For a valve set a typical running cost for both l.t. and h.t. is one penny per hour although for the most economical receivers using valves with 25-mA filaments, a value as low as 0.6 pence per hour is claimed. Thus the transistor set is cheaper to run by a factor of at least 3 and probably nearer 4 or 5 even though it gives two or three times the power output of a valve receiver and has better sensitivity. In addition the transistors are, of course, much smaller than valves, making possible very compact receivers; they are non-microphonic and have a longer life than valves. Their life is not unlimited (as has sometimes been suggested) but decreases as the operating temperature rises. Used in a receiver of the type to be described they should have a life many times that of valves. To offset these advantages the transistors are slightly more noisy than valves and at present they are more expensive.

Most battery-driven portable receivers have 4-valve superhet ciruits basically similar to those employed in mains-driven receivers but their performance is, in general, inferior because of the lower gain of battery valves and because the frame or ferrite-rod aerials of portable receivers do not give so good a pick-up as an outdoor aerial. This limitation in performance is usually accepted because, in spite of it, the sensitivity is usually adequate for the reception of the local stations even when the receiver is used in an unfavourable situation. Moreover, an improvement in performance would require additional stages of amplification and, in a

*B.B.C. Engineering Training Department.

battery superheterodyne receiver the frequency changer and i.f. stages account for a large fraction (between one-quarter and one-half) of the total power consumption. Thus extra stages must inevitably cause a significant increase in h.t. and l.t. drain. There is no need to accept such a limitation in the performance of a transistor receiver because the current taken by the early stages is a much smaller fraction of the total current drain and the increased consumption due to any added transistors is negligible. Thus there is no need to limit the number of stages on the grounds of running costs and the receiver can be given the maximum sensitivity likely to be required.

The required sensitivity was estimated by comparison with a mains-driven superhet recently described by the author[1]. This receiver needs a signal of approximately 20 μV (modulated to a depth of 30 per cent) at the output of the medium-wave ferrite-rod winding to give 300 mW output and it was decided that the transistor set should give its maximum output for a smaller voltage at the output medium-wave winding. High sensitivity is of little use, however, unless it is accompanied by high selectivity.

Class A or Class B?

We shall now consider the broad principles of design of a superheterodyne transistor receiver, beginning with the output stage. Here a choice has to be made between class-A and class-B operation. The quality of reproduction obtainable with a class-B stage is probably inferior to that from a class-A stage but it can be improved by negative feedback. However, too much importance should not be attached to this point; the small loudspeaker and limited baffle area of a portable receiver inevitably impose limitations of the quality realizable. A class-A stage could be only a single transistor and this can be RC-coupled to the previous stage; a class-B stage needs two transistors operating in push-pull and requires some form of phase-splitting device, such as a transformer with a centre-tapped secondary winding, between it and the previous stage. Moreover a class-B stage necessitates thorough decoupling of the supply to the frequency-changer and i.f. stages to prevent feedback of harmonics of the a.f. output and consequent distortion—we shall return to this point in Part 2. Thus the first cost of a receiver with a class-B stage is higher than that of a receiver with a class-A stage. However, the collector dissipation in a class-A stage is a maximum in the absence of a signal. Such a stage is more likely to suffer from thermal runaway with possible damage to the transistor than a class-B stage, and circuit precautions will be necessary to prevent this. This subject and that of protective circuits will also be discussed more fully in Part 2.

Efficiency

The running cost of a battery-operated receiver is probably more important than the first cost and depends on the efficiency of the output stage which in turn depends on the shape of the characteristics of junction transistors. The characteristics of an output transistor are illustrated in Fig. 1. They are practically straight, parallel and equidistant: moreover, the knee of the characteristics occurs at a very low collector voltage which means that the signal-frequency voltage generated across the transistor during amplification can nearly equal the battery voltage. As a result the efficiency of a transistor, i.e., the ratio of output power to the power taken from the battery, is near the theoretical maximum which, for class-A operation, is 50 per cent. This applies only on peak audio signals for which the transistor delivers its maximum output. If the output is not at maximum (and for music and speech signals the average level is below the maximum level for a considerable fraction of the total time) the average efficiency is much less than 50 per cent. For a class-B stage the efficiency does not vary greatly with the amplitude of the input signal and in practice can exceed 70 per cent. Moreover a class-B stage is a quiescent system; that is to say the collector current is very small in the absence of an input signal but rises with increase in input signal level. Thus the relative economy of the class-B output stage is greater than the ratio of the two efficiency figures suggests and the running cost of a receiver with a class-B stage is much less than that of a receiver with a class-A stage delivering comparable output power.

Thus the choice between class-A and class-B output is influenced by the relative importance of first cost and running cost. If running costs must be low a class-B stage is preferable. If running costs are not so important a class-A stage is preferable. It does not follow, of course, that a transistor set with a class-A stage will be expensive to run. Because of the superior characteristics of transistors it must be more economical than a valve set. As an illustration a transistor operating with, say, 22.5 volts supply can give an output of 100 mW for a collector current of 10 mA; this is approximately the power output of many valve receivers operating with 67.5-volt batteries. The transistor set requires no elaborate filtering of the supply to the early stages and the total battery drain is unlikely to exceed 12 mA at which even small cells should give a reasonable life. This could form the basis of a simple and compact superhet receiver.

Choice of Circuit

However, most of the transistors at present available in this country are intended for operation at lower collector voltages such as 6 or 9 volts. At 6 volts a class-A output stage must consume 33 mA to give an output of 100 mW. For such a stage the collector dissipation is 200 mW in the absence of an input signal. With little choice of output transistors at the moment, no type could be found which is suitable for such an application. Most of the available transistors are rated for dissipations of 100 mW or less and it was decided to use two of these in class-B push-pull for the output stage. From these it is possible to obtain more than 300 mW output without exceeding the maximum collector dissipation. The collector current rises to over 100 mA on programme peaks but the average is 25 mA, less than that required by a class-A stage to give 100 mW.

The output transistors can be operated in common-base, common-emitter or common-collector circuits. In a common-base amplifier the current gain of the transistors is less than unity and high gain is possible

[1] Amos, S. W., "Economy in Receiver Design," *Wireless World*, Aug., 1956.

only by using high load impedances and these are inconvenient in an audio output stage. The choice is thus between common-emitter and common-collector and in this receiver, as in most transistor-operated equipment, common-emitter working is preferred because of its higher gain. There is some distortion and a minimum of about 6 dB of feedback is advisable to improve linearity.

The maximum power output obtainable from a class-B push-pull pair is approximately four times the maximum permissible collector dissipation for each transistor, and if this is taken as 85 mW—a typical value—the power output is 4 × 85 = 340 mW. This peak power is equal to VI/2 where V is the peak collector voltage and I is the corresponding peak collector current. If P is the power we have

$$I = \frac{2P}{V}$$

For 340-mW output and a 6-volt supply

$$I = \frac{2 \times 340}{6} \text{mA}$$
$$= 110 \text{ mA.}$$

The optimum load for each transistor is given by

$$\frac{V}{I} = \frac{6}{110 \times 10^{-3}} \text{ohms}$$
$$= 55 \text{ ohms}$$

giving a collector-to-collector load of 220 ohms. From this the turns ratio for the output transformer can be calculated. If the loudspeaker is of 3 ohms impedance the ratio is given by $\sqrt{(220/3)} : 1$ which equals 8.5 : 1.

Driver Stage

If we take the current gain of the common-emitter output transistors as 50, the input current required for maximum output is approximately 2 mA. This is supplied by a driver stage, also common-emitter, coupled to the output stage by a transformer with a ratio of 1 : 1, the secondary winding being centre-tapped. Thus a 1-mA peak swing is required from the driver stage: the collector current for this stage must hence be at least 1 mA and is adjusted to at least 2 mA to allow a safety margin. If the current gain of the driver stage is also 50, an input current of 20 μA is needed for maximum output. The input resistance of common-emitter stages is usually of the order of 1 kΩ and the peak input signal required at the base of the driver stage is hence $20 \times 10^{-6} \times 10^{3} = 20$ mV. This could be supplied directly from the diode detectors but to obtain the gain from the pre-detector stages necessary to give the desired sensitivity at least three i.f. stages would be necessary. Some difficulty is likely to be experienced in stabilizing such an i.f. amplifier. Moreover, the gain of one a.f. stage is higher than that of one i.f. stage. It is therefore preferable to use three a.f. stages rather than three i.f. stages. The a.f. amplifier so obtained is very sensitive, requiring less than 1 mV input for maximum output, but the sensitivity is reduced by negative feedback applied from the secondary of the output transformer to the emitter of the first a.f. stage. This improves the linearity of the a.f. amplifier and also increases the input resistance of the first a.f. stage; a useful feature because, for a given degree of peak clipping in the detector stage, it permits the use of larger diode loads than would otherwise be possible.

The first a.f. stage is direct-coupled to the detector to give amplified a.g.c. Such amplification is necessary because it is impossible to obtain a large enough control voltage directly from the diode detector. There is a step-down ratio in the i.f. transformer coupling the final i.f. amplifier to the detector and the peak voltage swing at the collector must necessarily be less than the battery voltage: thus the signal delivered to the diode must be small and in fact is inadequate for giving effective a.g.c.

By using a three-stage audio amplifier the required sensitivity can be achieved with two i.f. stages and we will now consider the problems which arise in the i.f. section of the receiver. These differ markedly from those encountered in the i.f. section of a valve receiver. For example, the i.f. transformers in a valve receiver can be designed without regard to the input and output impedances of the valves with which they operate because the impedances are too high to have significant effect on the transformer performance. In a transistor receiver the damping due to the transistors has a very great bearing on transformer design: in fact, the input and

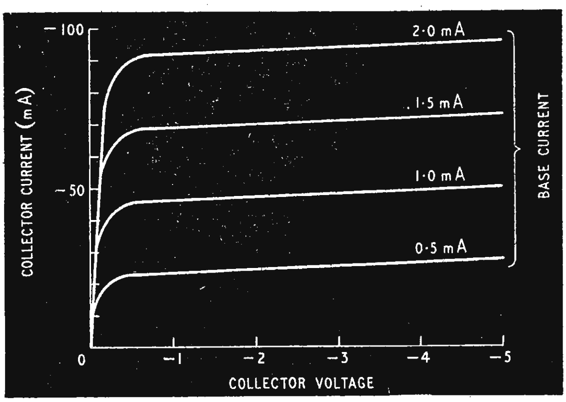


Fig. 1. Collector-current/collector-voltage characteristics for an open transistor.

output resistances largely determine the design and performance of the transformers.

These resistances depend, of course, on the type of amplifier used and here there is the usual choice between common-emitter and common-base circuits. In i.f. amplifiers general opinion is not so unanimously in favour of common-emitter working as in a.f. amplifiers. For a given alpha cut-off frequency a common-base amplifier will operate up to higher frequencies than a common-emitter amplifier and, where cut-off frequencies are low, the use of this type of amplifier is justified. However, the application of standing bias and a.g.c. bias to such an amplifier is difficult: if the base is connected to the positive terminal of the battery supply a yet more positive voltage is needed for the emitter bias. A common-emitter amplifier is more convenient to bias, and, as manufacturers steadily raise the cut-off frequencies of transistors, this type of amplifier is likely to become standard in time. If the emitter is connected to the positive terminal of the battery supply, the negative terminal can be used as a source of negative bias for the base. This mode of operation is used in the i.f. amplifier and in fact in all the stages of the receiver to be described.

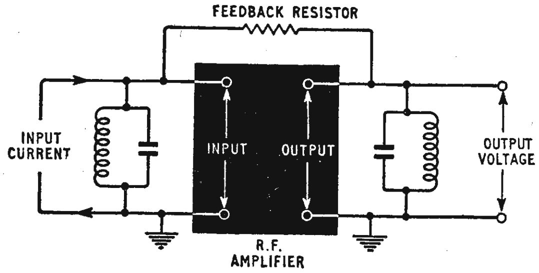


Fig. 2. Block schematic diagram for method of obtaining bandpass characteristics by means of negative feedback.

The i.f. amplifier provides most of the selectivity of the receiver and it was decided that four tuned circuits with an effective Q value of at least 100 were necessary to provide the desired selectivity. This is better than in many valve receivers where working Q values are commonly of the order of 70.

These four circuits can be arranged as a succession of single-tuned circuits or can be grouped to form two double-tuned circuits. Both arrangements give the same skirt selectivity; i.e., the same slope of response curve outside the pass band. However, a cascade of single-tuned circuits inevitably gives some side-band cutting, the extent of which can easily be calculated as follows. A single-tuned circuit resonant at 465 kc/s and with a Q of 100 has an effective bandwidth of 465/100 = 4.65 kc/s: that is to say the response is 3 dB down at 2.3 kc/s from the centre frequency. Four such circuits would therefore give a loss of 12 dB at this frequency, making reproduction very low-pitched. It is better to group the tuned circuits into pairs, coupling the members of each pair to give a bandpass response. Such an i.f. amplifier can be designed to give a substantially level response over the required pass band thus making possible better reproduction than is obtainable with single-tuned circuits. This is, of course, the basis of design of valve superheterodyne receivers where one double-tuned circuit is used to couple the frequency changer to the i.f. amplifier and a second is used to couple the i.f. amplifier to the detector.

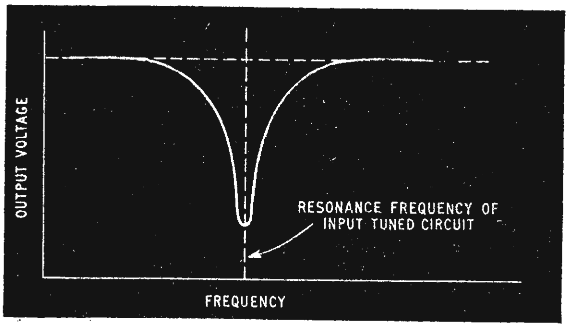


Fig. 3. Response of circuit of Fig. 2 when output load is a pure resistance

In the transistor receiver the design is not so straightforward. Two i.f. amplifiers require three inter-stage couplings, and introduce the problem of including two bandpass filters without using a further tuned circuit or an aperiodic network for one of the couplings.

One possibility is to use only one bandpass filter and two single-tuned circuits. The two single-tuned circuits will each give a loss of 3 dB at 2.3 kc/s mistuning giving a total of 6 dB. This can be offset by over-coupling the two tuned circuits forming the bandpass filter so that they give a response with "rabbit's ears" which neutralize the loss of the single-tuned circuits to give an overall response flat up to, say, 3 kc/s off tune. This is, however, an impractical solution. The peaks are usually of differing heights. Moreover, if the damping imposed by a transistor on one of the tuned circuits in the bandpass filter should change for any reason—say due to an alteration in a.g.c. bias applied to it—the Q of the circuit will alter and so will the height of the peaks. There will thus be significant changes in the shape of the pass band with changes in signal strength.

The solution adopted in this receiver is based on an idea described by Jewitt[2] which enables a bandpass response to be obtained from two single-tuned circuits which are separated by an amplifier. The explanation of the circuit can be followed from Fig. 2 which illustrates such an amplifier in block schematic form. The input tuned circuit forms the lower arm of a negative feedback potentiometer and therefore frequency-discriminating feedback is applied to the amplifier. Feedback is at maximum at the resonance frequency, less at frequencies slightly displaced from resonance and is practically nil at frequencies remote from resonance. If the amplifier has a load independent of frequency, such as a pure resistance, its frequency response will show a dip at the resonant frequency of the input tuned circuit as shown in Fig. 3. When the load resistor is replaced by a parallel tuned circuit the overall frequency response becomes a combination of the dip due to the input tuned circuit and a hump due to the frequency-selective load circuit. Depending on the degree of feedback this response can be flat-topped (corresponding to critical coupling in a conventional bandpass filter) or can have two peaks corresponding to greater-than-critical coupling. It is useful to remember that critical coupling is obtained when the feedback is adjusted to give 6 dB loss at the mid-band frequency. The effect of adjusting the feedback frac-

[2] Jewitt, H. S., "Wide-band I.F. Amplifiers," *Wireless World*, Feb., 1954.

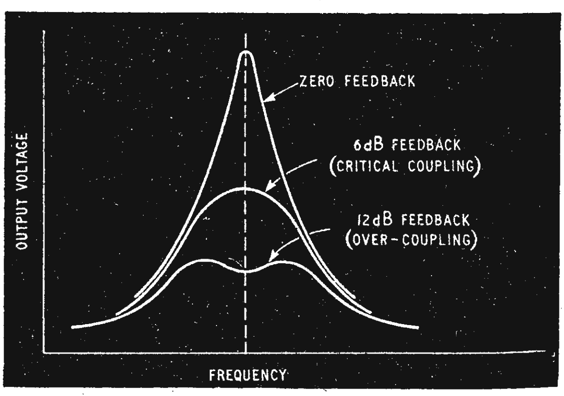


Fig. 4. Response curves of circuit of Fig. 2 for three degrees of feedback.

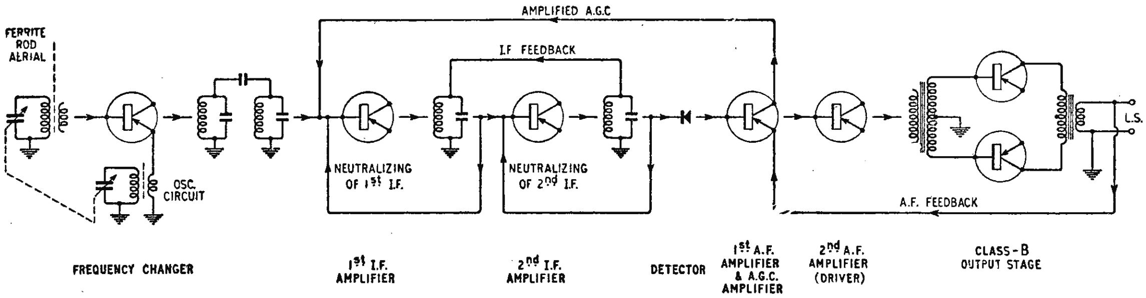


Fig. 5. Skeleton diagram of transistor receiver.

tion on the overall frequency response is illustrated in Fig. 4.

The third and fourth tuned circuits in the receiver i.f. amplifier are arranged to form a feedback amplifier of this type. The first and second tuned circuits are arranged as a conventional bandpass filter with top-end capacitance coupling. This is illustrated in the block schematic diagram of the receiver in Fig. 5. The coefficient of coupling used in the first bandpass filter must be chosen with care because the first i.f. amplifier is controlled from the a.g.c. line and the damping it imposes on the second tuned circuit can vary. If the coupling is made critical when damping is at maximum, "rabbit's ears" will develop when damping is reduced. It is better therefore to arrange to have critical coupling when damping is a minimum. When damping increases the coupling then becomes less than critical but the response is still single-peaked though the bandwidth is less than it was. This means that the receiver pass band varies with the received signal strength. This could be presented as a design feature—an automatic bandwidth control—but the truth is that the variations in bandwidth are difficult to avoid. Ideally the bandwidth should be independent of signal strength but if some variation is inevitable then it is better that the bandwidth should increase rather than decrease with increase of signal strength and it is fortunate that this is, in fact, what happens. The bandwidth is a maximum on local stations where best quality is required and a minimum on weak signals from which quality is often marred by noise and sideband splash.

I.F. Circuits

We now come to the design of the i.f. circuits themselves. In addition to providing the required selectivity these must also match the output resistance of one transistor (approximately 30 kΩ) to the input resistance of the following one (approximately 1 kΩ) in order to provide maximum gain. They must in fact behave as matching transformers and have a turns ratio given by $\sqrt{(30\text{ k}\Omega/1\text{ k}\Omega)} : 1$; i.e., approximately 5.5 : 1. The connections of collector and base to the tuned circuit must hence be chosen to give this turns ratio and to give the desired working Q value of 100. One possibility is to connect the transistors to tapping points on a parallel-tuned circuit as suggested in Fig. 6. The steady voltages on collector and base differ and blocking capacitors must be used to transfer signals from the tuned circuit to the transistors.

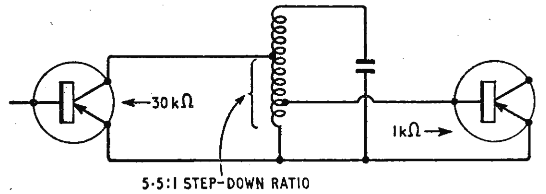


Fig. 6. Use of tappings on parallel-tuned circuit to match the output resistance of one transistor to the input resistance of the next.

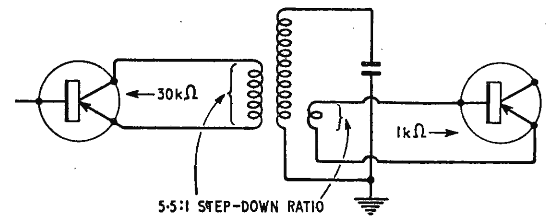


Fig. 7. Use of primary and tertiary windings to match the output resistance of one transistor to the input resistance of the next.

A better method is to employ separate windings for collector and base as in Fig. 7. the tuned circuit thus has three windings; a primary connected to the collector, a secondary which is tuned to 465 kc/s by a parallel capacitor and a tertiary which is connected to the base. The turns ratio of primary to tertiary must be 5.5 : 1; we now have to determine the turns ratio of primary to secondary. This is determined by the permissible damping of the tuned circuit. If the secondary circuit has a high Q—say 300—the ratio of primary to secondary turns can be so chosen that the damping due to collector and base together brings the Q down to one-third of its original value; i.e., to 100. On the other hand if the undamped Q is only 150 the damping must be much lighter to give a working Q of 100. Both arrangements give the same selectivity but the gain is higher with the higher initial Q. Webster[3] has shown that if the Q is reduced to half there is a 6 dB loss relative to the maximum gain theoretically possible. If the Q is reduced to one-third the loss is 4 dB and if it is reduced to one-quarter the loss is only 2.5 dB.

For maximum gain therefore it is best to design for the highest undamped Q but there are then large changes in damped Q and therefore in the i.f. response curve when the damping due to the transistors alters

[3] Webster, R. R., "Designing I.F. Transistor Transformers," *Electronics*, Aug. 1955.

as a result of a.g.c. action. A compromise is required and it is probably best to accept the 6-dB loss and to arrange that the Q is reduced to half by transistor damping. The removal of one source of damping due to a.g.c. can then at worst cause only a 32 per cent change in damped Q. In the receiver to be described two losses of 6 dB each are suffered by adopting bandpass circuits and it was decided to use undamped Qs of 300, which are reduced to 100 by transistor damping. The change in Q due to removal of damping due to one transistor is then 50 per cent but this is allowed for, as mentioned earlier, by arranging that the bandpass filters are never more than critically coupled.

The output capacitance of a transistor in a common-emitter circuit is of the order of 30 pF but can vary by as much as 18 pF with the bias current. Hence the i.f. transformers must be so designed that these variations do not significantly alter the tuning. This requires that the equivalent capacitance across the primary winding should be large enough to swamp possible output-capacitance variations. If we decide that mistuning shall be limited to one-half per cent (2.3 kc/s in 465 kc/s) the capacitance change must be less than one per cent. If the output capacitance changes by 18 pF, the equivalent primary capacitance should not be less than 1800 pF: in fact it is 3200 pF.

The frequency changer stage can be a self-oscillating mixer requiring only one transistor or can consist of a separate oscillator and mixer which requires two transistors. The two-transistor circuit has slightly higher conversion gain and has the advantage that a.g.c. can be applied to the mixer stage. However, the gain of the receiver is quite adequate with a self-oscillating mixer and, to economize in first cost, this form of circuit was adopted. Not all r.f. transistors are successful as frequency changers: some which are quite satisfactory as i.f. amplifiers fail to oscillate or oscillate only over part of the band. Careful selection is thus necessary to find a suitable transistor for this position. Some transistors are marketed specifically as frequency changers and with these no difficulty has been found in securing a good performance over the whole of the medium waveband.

In addition to giving complete medium waveband coverage the receiver was designed to receive the Light Programme transmission on 200 kc/s. This was achieved, as in another receiver described by the author[4], by adding sufficient parallel capacitance to the medium-wave oscillator circuit to bring the resonance frequency down to 665 kc/s when the tuning capacitor is at its mid-setting. The switch used also selects a fixed-tuned long-wave winding on the ferrite rod. No difficulty was experienced on maintaining oscillation at 665 kc/s in spite of the reduced L/C ratio.

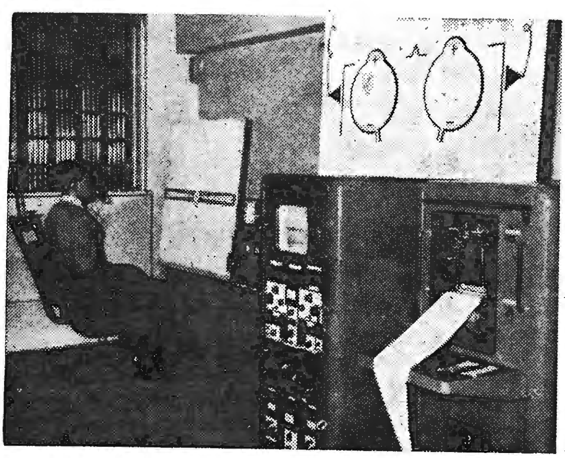
A block schematic diagram of the complete receiver is given in Fig. 5 showing the links between the stages for a.f. feedback, i.f. feedback, neutralizing and a.g.c. A full circuit description will be given in a later issue.

[4] Amos, S. W., "Design for a Car Radio," *Wireless World*, Dec., 1956.

PLOTTING EYE MOVEMENTS

A Method Depending on the P.D. between Cornea and Retina

MUCH has been heard of motion study for the reduction of manual fatigue in repetitive manufacturing operations, but less of eye fatigue in tasks calling for visual concentration on, say, a number of dials or meter readings. If the operator's eye movements could be analysed it should be possible to devise an arrangement of the indicators which requires the minimum effort for supervision.



Equipment for electro-oculography made by E.M.I. for the Naval Motion Study Unit of the Admiralty Research Laboratory.

Optical methods, such as corneal reflections and cinematography, have in the past been used to plot movements of the eyes when the subject has been set a visual task, but these have left something to be desired either on the score of convenience or accuracy. A new method depends upon the fact that a difference of potential exists between the cornea and the retina of the eye. If electrodes are applied to the surface of the face adjacent to the eye, any movement from a median position can be resolved into horizontal and vertical components from the alteration in potential of the skin electrodes, which are disposed in pairs on lines which would intersect at the centre of the iris.

The results may be plotted by a pen recorder or displayed in two dimensions on a cathode-ray tube—a method developed by Dr. N. H. Mackworth of the M.R.C. Applied Psychology Research Unit, Cambridge.

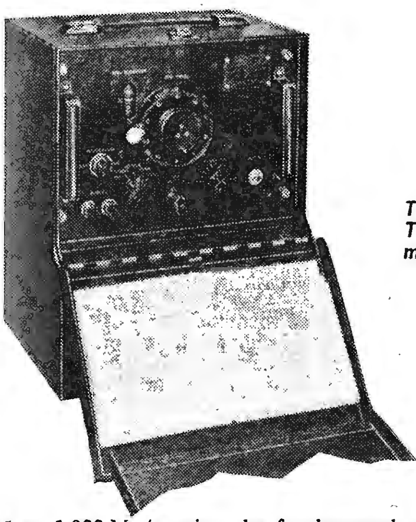
The potential differences are small, 15 to 20 μV per degree of movement of the eye, and special twin-channel d.c. amplifiers have been developed by E.M.I. Electronics, Ltd., for this application with gains of the order of 10,000. Feedback is frequency-dependent and is designed to reject mains interference while preserving a short rise time for step changes of input. Each amplifier is provided with a backing-off circuit to compensate for standing potentials, which vary between individuals, at the arbitrary "zero" position of the eye. Zero drift in the amplifier is less than 20 μV in 30 minutes.

Manufacturers' Products

NEW ELECTRONIC EQUIPMENT AND ACCESSORIES

V.H.F. Measuring Sets

TWO self-contained, portable frequency meters for accurate measurement of frequency up to 1,000 Mc/s have been introduced by Telemechanics, Ltd., 3, Newman Yard, Newman Street, London, W.1. One, the Type 7474, covers 20 to 250 Mc/s and the other, Type 7475,



Telemechanics Type 7475 v.h.f. measuring set.

85 to 1,000 Mc/s using the fundamental and harmonic frequencies of the internal oscillator in each case.

Signals are picked up by a short aerial, heterodyned to zero beat and the frequency read off tabulated charts, housed in the drop-down cover, from dial readings. An accuracy of 0.002% at 25°C is claimed.

The sets can be used also as radiation-type signal generators with or without modulation at 1,000 c/s. While normally battery operated, provision is made for substituting a mains power unit if required. The price of each model is provisionally fixed at £245.

Record Handling

A USEFUL tool for holding gramophone records has been produced by Claravox Products Ltd. This enables records to be gripped by rubber-covered tongs at the edge and in this way the delicate playing surface of long-playing records can be protected against dust-collecting fingerprints. This instrument will perhaps be of most use in withdrawing records from their envelopes; if this is done by hand alone it is difficult to avoid touching the playing surface. Care must be taken to avoid flexing the record about the clamp—neglect of this precaution with shellac records could lead to breakages.

The instrument is called a Miragrip, the price is 18s 6d, and the address of the makers is 465 Walsgrave Road, Coventry.

"Semi-Communications" Receiver

THE illustration shows a broadcast set having the rugged qualities, precision tuning and many features of a communications receiver. It is the new Eddystone Model 870 and as it is designed for operation on 110 V or 200/250 V d.c. or a.c. supplies it is particularly suitable for use on board ship. In addition to medium- and long-wave bands the set has two short-wave ranges, covering between them 1.95 to 18 Mc/s.

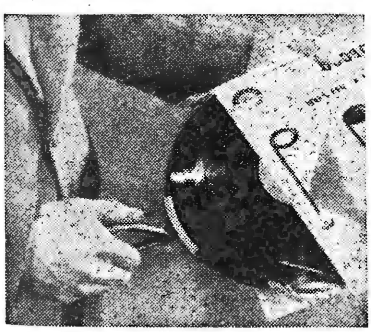
The circuit is reasonably orthodox and consists of a heptode frequency changer; pentode i.f. (465 kc/s); d-d-triode, detector, a.g.c. and a.f. and a tetrode, with negative feedback, feeding a built-in loudspeaker. An i.f. rejector is embodied in the aerial circuit and a filter in the mains leads to smooth out any "roughness" in ships' electric supplies. Thermistors and fuses safeguard the valves and the set.

Like other Eddystone sets the dial occupies the full width of the front and a long pendant pointer traverses the four full-length, frequency-calibrated scales as well as a special logging scale.

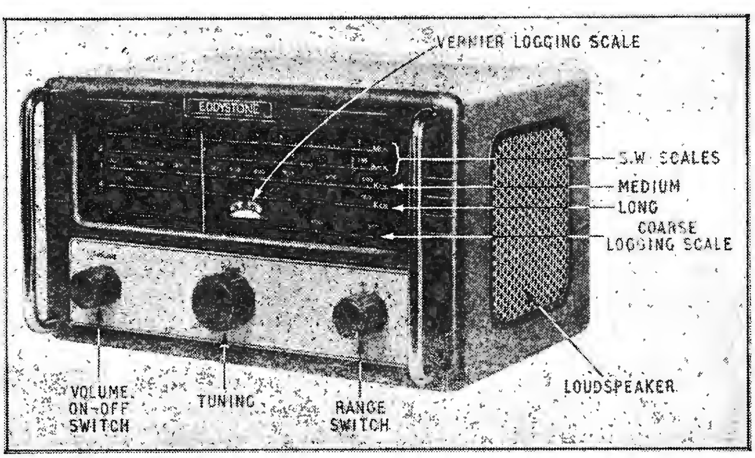
Just above the last-mentioned is a small window through which is viewed a vernier logging scale which, used in conjunction with the coarse logging scale, enables the dial settings of stations to be recorded precisely for future occasions. This is invaluable on the very crowded short-wave bands.

The "870" is housed in a two-tone grey metal cabinet measuring 11in × 6⅜in × 8¼in, it weighs 11½ lb and has tropical finish throughout.

The makers are Stratton and Co., Ltd., Alvechurch Road, West Heath, Birmingham, 31, and the price is £24 plus £10 16s U.K. purchase tax.



Claravox Products "Miragrip."



Eddystone Model 870 broadcast receiver.

News from the Industry

R.E.C.M.F. Council.—At the annual general meeting of the Radio and Electronic Component Manufacturers' Federation on March 19th the representatives of the following firms were elected to the 1957/58 council: the representatives' names are in parentheses. Colvern (H. J. Mildren), De La Rue (C. R. Jennings), Garrard (H. V. Slade), Gresham Transformers (J. P. Coleman), Morganite Resistors (J. Thomson), Multicore Solders (R. Arbib), N. S. F. (K. G. Smith), Painton (C. M. Benham), Plessey (P. D. Canning), S.T.C. (E. E. Bivand), T.C.C. (W. F. Taylor), T.M.C. (E. Lawrence), Bulgin (A. F. Bulgin), Belling and Lee (E. M. Lee), A. H. Hunt (S. H. Brewell) and Wingrove and Rogers (A. J. D. Dobie). The chairman is Richard Arbib and the vice-chairman K. G. Smith.

A. B. Metal Products, Ltd., of Abercynon, Glamorgan, has been acquired by Gas Purification and Chemical Company. A. B. Metal Products have recently concluded an agreement with Standard Coil Products Inc., of Illinois, permitting them to manufacture under licence a "revolutionary type of television tuner." It is expected to be in production by the autumn. Among the companies already in the Gas Purification group are Grundig (Great Britain), tape recorders; Wolsey Television, aerials; Electric Audio Reproducers, sound reproducing equipment; Staar Electronics, record players; Kingsway of London, audio equipment; and Besson and Robinson, relays.

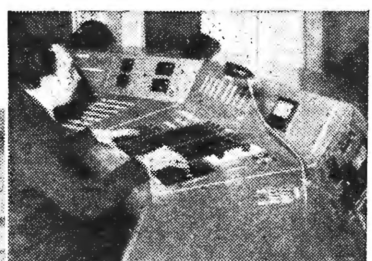
Peña Copper Mines, Ltd., are entering the field of electronics and have arranged to acquire an interest in three companies. The first to be announced is **Peto Scott Electrical Instruments, Ltd.,** of Weybridge.

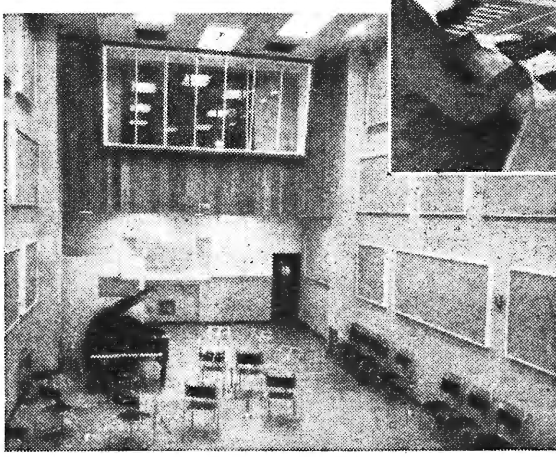
H.M.V. - Ferguson Merger. — A new company is being formed jointly by Electric & Musical Industries, Ltd., and Thorn Electrical Industries, Ltd., for the design and marketing of all domestic sound and television receivers under the Ferguson, H.M.V. and Marconiphone trade-marks. Production will be mainly centred at the Thorn factories at Enfield, Middlesex, and Spennymoor, Co. Durham.

E.M.I. Records, Ltd., has been formed by Electric & Musical Industries to co-ordinate the production, manufacture, marketing and distribution in this country and abroad of H.M.V., Capitol, Columbia, M.G.M., Parlophone and Regal-Zonophone records.

A modified version of the "Radiopage" r.f. induction staff-locating system (see *W.W.*, July, 1956) has been purchased from **British Communications Corporation** by the Royal Navy for operational trials as a flight-deck communications system in aircraft carriers. Key men in the flight deck party will carry miniature receivers with earpieces in their noise-excluding helmets. As transmissions are not radiated outside the immediate area of the flight deck, secrecy requirements are fully met.

Technical Manuals.—British manufacturers obtaining contracts with the U.S. Department of Defense, which call for literature to U.S. specifications, may like to know an American company, Warner New York Corporation, is prepared to assist directly or indirectly in the preparation of such literature. Information is obtainable from the general manager, Alfred Dinsdale (a contributor to *Wireless World*), at 750, James Street, Syracuse, 1, New York.





PHILIPS new recording studio at Stanhope House, Stanhope Place, London, W.2, can be booked by organizations or individuals for all types of recording. From the console (inset) the recording engineer has complete remote control of the recording facilities, which include tape and disc

Data Recording Instrument Co., Ltd., with works at Hanworth Trading Estate, Feltham, Middlesex, has been formed to make components for computers. The company is initially concentrating on magnetic recording and reading heads. Among the directors are J. P. Coleman, founder and managing director of Gresham Transformers, and a director of Lion Electronic Components, and Dr. C. B. Speedy.

Murphy v.h.f. radio-telephone equipment, including a base station (MR862) and eight mobile units (MR800), has been installed for the South Devon Water Board by R. B. Holman, radio dealers, of Kingsbridge and Salcombe, Devon.

The manufacturers of Raymond and Beethoven television receivers have made arrangements with **Direct TV Replacements** (134-136, Lewisham Way, London, S.E.14) for them to manufacture replacement components for all models other than the current range. The main components included are e.h.t. line output transformers, frame transformers and deflector coils. Direct TV Replacements already have similar arrangements regarding Baird, Etronic and R.M. Electric receivers.

WORKS EXPANSION

A five-storey building in Liverpool, with a floor space of 55,000 square feet, has been purchased by **Automatic Telephone & Electric Company** to expand production in the electronics field. This is in addition to the company's main factory at Strowger Works and several other smaller factories in the area.

Building has started on a new 45,000-sq ft factory at Martin Street, Airdrie, for the Pye subsidiary, **Pye Scottish Telecommunications, Ltd.** The present factory employs about 130 and produces 1,000 broadcast receivers a week, of which roughly one-third is exported. The new factory, which should be ready next March, will employ over 400.

Fringevision, Ltd., television aerial manufacturers, of Elcot Lane, Marlborough, Wilts., are extending their factory buildings; when completed, floor space will be trebled to 15,000 square feet.

Trix Electrical Company, of Maple Place, London, W.1, have acquired additional factory premises at Wish Road, Eastbourne, for the production of sound reproducing gear.

NEW ADDRESSES

Modern Techniques (S. Korobuk, Ltd.), makers of **Motek tape recorders,** have closed their two factories in north London and have moved to larger premises at Wedmore Street, London, N.19. (Tel.: Archway 3114.)

Tellux, Ltd., distributors of **Telefunken** receivers, components (including transistors) and accessories, have moved from Kensington to 146, New Cavendish Street, London, W.1. (Tel.: Langham 2411.)

Telerection, Ltd., aerial manufacturers, of Cheltenham, Glos., have opened a wholesale depot at 149, Lower Cheltenham Place, Bristol. (Tel.: Bristol 57888.)

The new address of the Bristol depot of **Aerialite, Ltd.,** is Portland House, Portland Square. (Tel.: Bristol 26130.)

OVERSEAS TRADE

Provisional figures for the radio industry's **exports in February** are the highest on record for that month—£3.62M—and £400,000 more than in January.

South Africa has been added to the list of countries—including Australia, New Zealand, India, South America and Eire—in which E. K. Cole have financial interests in manufacturing companies. The export of goods from the U.K. to each of these countries is restricted. The new member of the Ekco overseas companies is Kruger & Wilson, Ltd., which represents them in South Africa and the Rhodesias.

The complete **nucleonic instrumentation** and control circuitry for the first experimental atomic reactor to be exported from this country is being supplied by Ekco Electronics, Ltd. The equipment is for the Australian reactor to be built at Lucas Heights, near Sydney.

S.H.F. Radio Network.—The installation of a chain of radio stations between Osaka and Fukuoka, Japan, covering a distance of nearly 400 miles, has been completed by Standard Telephones and Cables through their associates, the Nippon Electric Company, of Tokio. The network, including eleven intermediate repeater stations operating in the 3800-4200-Mc/s band, provides for three two-way channels. One will be used for a television link, another for 240 telephone channels, and the third kept as a stand-by for either television or telephony.

Milan Fair.—Among the 400 exhibits selected by the Council of Industrial Design for the Board of Trade's stand at the International Samples Fair, Milan (April 12th to 27th), is the Ekco portable television set. The Pye "Jewel Case" portable sound receiver, Ekco U245 medium- and long-wave table receiver, and a portable electric gramophone by Electric Audio Reproducers, are also included.

F.M. Transmitters.—The Swedish Royal Board of Telecommunications has placed orders with Marconi's for the supply of twelve 5-kW frequency-modulated v.h.f. broadcasting transmitters together with three combining units. One transmitter has already been supplied and is in operation at Ostersund.

Two transmitters (5 and 7.5 kW) have been ordered from Marconi's for the Aden broadcasting service. They are due to be brought into service this summer.

Guy Barreyre, of 114, Rue Dantes Destouches, Port-au-Prince, Haiti, would like to represent a leading United Kingdom manufacturer of **domestic broadcast receivers.**

An order for tens of thousands of Monarch **automatic record changers** has been placed with Birmingham Sound Reproducers, Ltd. by a German radio manufacturer.

MAY MEETINGS

LONDON

2nd. London U.H.F. Group.—"Amateur television convertor for u.h.f." by a member at 8.0 at the Bedford Corner Hotel, Bayley Street, W.C.1.

6th. I.E.E.—Discussion on "The co-ordination of education and practical training in sandwich courses" opened by C. Grad and A. Draper at 6.0 at Savoy Place, W.C.2.

6th. Institution of Post Office Electrical Engineers.—"The Rugby 'B' h.f. radio transmitting station" by A. Cook and L. L. Hall at 5.0 at the I.E.E., Savoy Place, W.C.2.

15th. I.E.E.—"Transistor circuits and applications" by A. G. Milnes at 5.30 at Savoy Place, W.C.2.

22nd. Brit.I.R.E.—"Barium titanate storage cells" by G. Campbell at 6.30 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

23rd. I.E.E.—"General applications of digital computers" by Dr. A. D. Booth at 6.30 at Savoy Place, W.C.2.

25th. London U.H.F. Group.—U.h.f.-v.h.f. convention from 10.0 a.m. at the Bonnington Hotel, Southampton Row.

MALVERN

3rd. Brit.I.R.E.—"Marine radar" by H. R. Whitfield at 7.0 at the College of Electronics.

RYDE (Isle of Wight)

9th. I.E.E.—"Colour television" by C. J. Stubbington at 6.30 at the Ryde Castle Hotel, The Esplanade.

TORQUAY

9th. B.S.R.A.—"A quart in a pint pot: the development of a loudspeaker" by A. R. Neve at 7.30 at Callard's Café.

RANDOM RADIATIONS

By "DIALLIST"

The Kingsand Effect

SEVERAL interesting letters have reached me on the subject of the Kingsand Effect, which was described on p. 102 of the March issue. One of my correspondents, M. E. Northey, lives at Belstone, near Okehampton, close to the 1,000ft above m.s.l. contour. He is only 12 miles from North Hessary Tor, but obtains very poor reception from that station. His home is three miles from Steeperton Tor (1,739ft) and one mile from Belstone Tor (1,568ft). The direct line from his aerial passes between the two over an intervening ridge. He obtains a venetian blind type of patterning which travels upwards over the picture, one line taking about three seconds to move from bottom to top. Then after a period varying from 2½ to 3½ minutes on different days the pattern changes its direction and travels downwards. There is some variation in the brightness, though this is not as a rule very pronounced. Mr. Northey mentions that Dartmoor is very rich in metallic deposits (it was for centuries an important tin-mining area) and wonders whether this might be the reason for the reflections that give rise to the interference. I suppose that's a possibility; but I'm more inclined to think that the French TV transmitter at Caen may be responsible. Its 819-line transmissions cover the whole of our Channel 1 and a good deal of Channel 2, the latter being the one used by North Hessary Tor. My correspondent mentions that he has occasionally heard French speech.

Sunspots to Blame

Mr. Northey wonders whether Holme Moss, also on Channel 2, could not be the culprit. There have, if I remember aright, been complaints of interference due to this station at surprisingly great distances. If it is the offender in the present case, the effect would undoubtedly be due to the freak long-distance reception so frequently reported during the present sunspotty period. This doesn't seem unlikely since very good reception is sometimes obtained at Belstone from Sutton Coldfield, which is 145 miles away. I suppose that when we have passed the sunspot maximum and begin to get nearer and nearer to the minimum, interference at great distances will become steadily less and less. Let's hope so anyhow.

Poor Fish!

WHEN you think of the relentless way in which they're harried day in, day out, night in, night out all through the year, you might be tempted to wonder that there are any fish left, particularly in such hard-fished waters as those that surround these islands of ours. The modern trawler (which costs almost as much as a destroyer of yesteryear) carries a remarkable amount of electronic equipment. One gadget in particular, the fish-finding echo-sounder, is a very deadly weapon. It can be set to give distant "views" of quite large areas of water as the ship steams along in search of her quarry. Then when the right indications are seen it can be switched so as to show a close-up of a limited area. From the size of individual members of the shoal, their formation and their movements the fish can be identified with something like certainty by a practised eye. If they're of the kind wanted, down goes the trawl and a good catch is a certainty.

For It Again

And now one reads of still another anti-fish device, which has given very promising results in experimental trials by Pye. It consists of a torpedo-shaped case, containing a device working on echo-sounding principles by transmitting a.f. pulses down towards the sea bed. It is towed by a helicopter, flying low over the surface, and signals from it travel up leads incorporated in the towing cable to a display unit in the aircraft. The big advantage is this. To make use of her fish-finding gear a trawler has to steam at no very great speed and it may be hours, or even days, before a shoal of worth-while size is found. The helicopter travels much faster and in a given time can cover a far greater expanse of water with her towed locator. As soon as she has a find, she transmits the position to the fleet which she serves and the hunt is on without a moment's waste of time. This is but one of a number of applications of echo-sounding from the air, which include salvage work and mine detecting. Electronic gadgets aren't always used to catch fish. Much use is made by marine biological establishments of the underwater television camera for the study of the breeding places and breeding habits of fish, so as to enable as much protection as possible to be given where it's needed.

Keeping Up With the Joneses?

THE tendency is for the living rooms of to-day to be quite small compared with those of years ago; yet one finds people going in for larger and larger TV screens. How many homes do you know in which people have 17-inch or 21-inch sets and can't (at any rate, in winter time) sit far enough away from them to rid the picture of lininess? I know quite a few. There's an idea amongst the uninitiated that you see more on a large screen than on a small one. You don't, of course, and if you sit at the proper viewing distance from each, a 12-inch screen gives exactly the same sized image on the retina as one with a larger screen. With a 405-line standard a useful rule of thumb is that for people with normal vision the minimum viewing distance in feet is half the screen size in inches. You can sit nearer than that with the 625-line standard used in most continental countries which have television services and still nearer to a screen displaying the admirable French 819-line picture. I hear that 30-inch c.r.t.s are appearing in America. If they are developed here there'll be a rush for them by the 14-inch Browns, who want to go one better than the 17-inch Robinsons and the 21-inch Joneses! But how are they going to contrive an eye-to-screen distance of 15 feet in their bungalow?

Where Your Money Goes

A KIND reader sends me a copy of the Post Office Engineering Union's *Journal*, which gives an interesting account of the way in which the £3 that we pay for our combined sound and television licence is absorbed. The G.P.O.'s share is 4s, which seems modest when you come to think that it pays not only for the work of issuing the licences, but also for the services of those most helpful and obliging P.O. engineers who come to our aid when we're troubled by interference. The Government's whack is 5s 4d, which, I imagine, just goes into the general kitty. The B.B.C. gets what's left, £2 10s 8d, of which 16s 11d is applied to sound broadcasting and £1 13s 9d to television.

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RANDOM RADIATIONS

By "DIALLIST"

The Kingsand Effect

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UNBIASED

By FREE GRID

Why 0—V—1?

I WONDER how many readers under thirty years of age will have any idea what 0—V—1 means? Very few I think, and yet in the twenties and early thirties this piece of shorthand was as well known as the vital statistics of film stars are to-day.

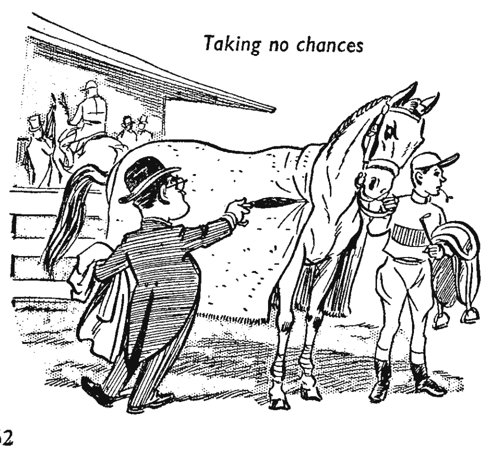
For the benefit of the new generation I would like to explain that in pre-superhet days this trinity of symbols told us at a glance the number of valves, if any, the set contained, their functions and if the set used a valve (V) or a crystal (C) as a rectifier. A 0—V—1 set therefore had no r.f. stage, used a valve rectifier and had one a.f. stage.

I am moved to discuss this question because this method of describing a set is used in a recent issue of the Russian journal *Radio*. There is nothing strange about the 0 and the 1 being used as the Russian numerals are the same as ours. But the Russian word for valve is "lampa" and one would therefore have expected the Cyrillic equivalent of the letter L—a slight variant of the Greek lambda—to have been used.

It cannot be doubted that the readers of this Russian journal fully understand the meaning of the expression 0—V—1 or the editor would not permit his contributor to use it. But probably some of the Russian readers don't understand what the "V" stands for; in that respect they are no more ignorant than many people in this country who could not say exactly what Latin words are represented by £sd—especially the s.

R.I.C. Please Copy

ON SEVERAL occasions I have pointed out the difficulties of trying to choose between the various makes of any particular product shown at the National Radio Show. Suppose, for instance, I want to buy a tape recorder. When I go to the radio show I naturally want to look at all the various makes and compare one with another as we do the horses in the paddock at Ascot before we place our humble bets.



Taking no chances

But at the radio show the state of affairs is quite different from that prevailing at Ascot. Having seen one tape recorder I have got to fight my way through the crowds to the far end of the exhibition hall to the stand of the manufacturer of the second instrument on my list.

I have often advocated that while each radio manufacturer continued to have a stand of his own as at present there should be other stands on which all tape recorders, all f.m. receivers, all television receivers, etc., of whatever make, be grouped together. Visiting the Ideal Home Exhibition a few weeks ago, I found that the electrical industry had done this very thing.

Each of the large manufacturers had his own stand on which he showed the usual motley collections of cookers and kettles. But in addition there was one very large stand run by the electrical industry on which all makes of water heaters, cookers, and so on, were grouped together. I was able to compare one with another in comfort.

Actually I was told this stand was run by the Electrical Development Association. Why have we no similar organization in the radio industry? If we have, then its publicity man ought to be sacked, as I have never heard of it.

Statogenetics

I HAVE received some interesting data from a South African radio engineer regarding the use of a dangling chain for conducting to earth the static charge on the body of a car about which I wrote in February.

In the Kimberly district, which is 4,000 feet up and where the air is very dry, static discharges are one of life's bugbears, and my correspondent mentions that when his wife brushes her hair it results in crackling static. Over a quarter of a century ago I referred in these columns to a similar sort of thing happening when a lady removed her silk stocking and I reproduce my sketch in the next column.

Actually the same problem arose many years later when TV came to the fore. Considerable interference was noticed in the vicinity of a well-known girls' school when several hundred pairs of stockings were whisked off at bedtime. It was at first proposed to stop the trouble by encasing the dormitories in earthed wire netting, but it was thought that uncouth people of the sort who are fond of expressions with a double meaning might refer to the school as the "bird cage." The problem was, however, instantly solved when the headmistress installed TV for her own use. The girls were sternly ordered, *sub pœna*, to remove all statogenic garments in slow motion.

Shocking

My Kimberly reader tells me that anybody alighting from an unearthed car obtains quite a healthy shock as the dry climate results in the building up of a strong static charge. At one time all motor vehicles carried a dangling chain but nowadays the problem is solved by using tyres processed with more carbon in the rubber, so greatly reducing their insulating properties. I am interested to learn, however, that car sickness from static build-up has not been heard of by my correspondent. This confirms my own view that the vogue for this malady in this country is due solely to suggestion.

Wot! No F.M. Aerial?

WHILE prowling through the Ideal Home Exhibition I was interested to note that on the full-sized houses erected in the vast exhibition hall TV aerials were fitted. But not one of the houses I examined had a horizontal dipole for v.h.f. sound broadcasting.

This set me examining houses in the Greater London area, and I have been astounded at the scarcity of v.h.f. aerials. I am perfectly aware that in most London districts Wrotham comes in well without the help of an outdoor dipole. So does television in many London districts, but the majority of people use an outdoor aerial.

Can it be that, unlike TV, a v.h.f. aerial has no snob appeal?