Wireless World

ELECTRONICS, RADIO, TELEVISION

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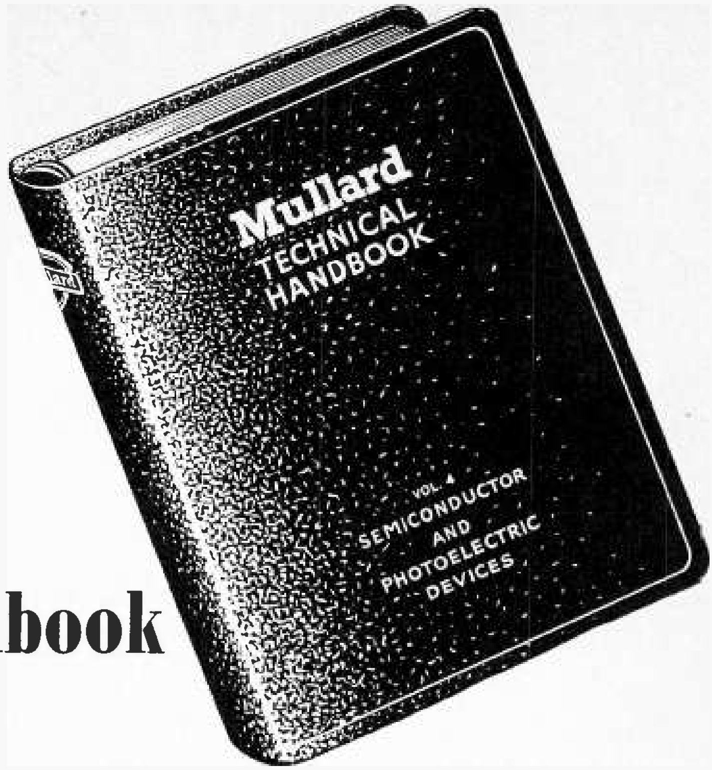
Introducing an addition to the Mullard Technical Handbook



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Wireless World

Stereophony on Trial

FOR more than a quarter of a century the subject of stereophony has been debated in the pages of this journal. Much of the argument in the past has of necessity been of a theoretical and speculative nature, but since the introduction of stereo tape and disc records and of experimental two-channel broadcasting by the B.B.C. it has been possible to refer hypothesis to the arbitration of experiment. Far from settling matters, this seems so far to have engendered fresh and even more vehement argument.

We think it likely that a public opinion poll conducted at this stage would find roughly equal numbers "for" and "against" but a far larger entry in the "don't know" category.

Those "for" would unquestionably include all who have been privileged to hear stereophonic reproduction in the research and development departments of the leading recording companies and of the B.B.C., under controlled conditions and with the best of equipment, regardless of cost. It would no doubt also include those who were fortunate in their choice of demonstrations at the Audio Fair and the Radio Show.

Among those "against" would be found the less fortunate in their choice of demonstrations, who may be forgiven for regarding the whole business as a "gimmick" to promote sales; also many "hi-fi" enthusiasts who are loath to admit that their single-channel equipment, on which they have recently spent large sums of money and which they regarded as the ultimate in performance, is capable of improvement. Some find the enveloping effect of stereophony tiring or even mildly claustrophobic, though they are not so affected by the multiple reflections, by the walls of the room, of the sound from a single loudspeaker. This is understandable, because the listener's aurally conditioned reflexes—the result of past experience—and the activity of his imagination are important factors influencing his judgment. Whatever the system, the sounds presented to his ear are a complex from which he can accept or reject only a fraction of the available clues to build up his perception of the information conveyed. Many people find all they need in the sound resulting from the skilfully employed microphone techniques of single-channel broadcasting and recording. The aurally literal and less imaginative welcome stereophony as an obvious necessity.

The "don't knows" include many far from "clueless" individuals who derive real enjoyment from single-channel sound, supplemented perhaps by individual methods of dispersal by reflection or the use of multiple speakers. They find good stereophonic demonstrations equally satisfying but not obviously superior, and understandably hesitate to incur the expense of revising and adding to their equipment. Hitherto no means has been available for comparing single-channel with stereo by a direct switch-over. Test records which merely switch off one channel would be obviously useless and paralleling the outputs of microphones placed for two-channel stereophony must always give poorer results than those obtained when there is complete freedom of choice of characteristics and position for the best single-channel balance. The only fair test is a comparison of simultaneous reproduction through single-channel and separate stereo channels, each system using its own microphones placed in the optimum positions, regardless of the technique being employed in the other system. Separately recorded disc records are possible, but might meet with synchronization difficulties on playback. Simultaneous recording on three tracks of a magnetic tape would be better but would require special apparatus. Broadcasting is obviously the best medium for tests of this kind and the B.B.C.'s experimental "live" stereophonic broadcast of January 24th, although not intended for this purpose, could have been so used. The closely spaced stereo microphones supplying the Network Three and TV sound channels were introduced and used separately from the normal microphone arrangement used for the regular single-channel broadcast of "Saturday Club" which went out as usual on the Light Programme.

A final appraisal must await the initiation of a regular broadcast service which, among other things, may depend on some modification of the two audio channels to make them "compatible" and capable of being broadcast through a single transmitter. Now is the time, however, to start to reduce the ranks of the "don't knows" by presenting for their choice a clear comparison of the best single-channel technique with the best stereophonic reproduction.

Although many high-quality enthusiasts have enough gear lying around to mount this experiment for their own satisfaction, the onus of demonstrating to the public at large must rest with the more enlightened dealers—and, of course, with the B.B.C. on whose continued co-operation the success of such tests must ultimately depend.

Time Past — SPARK AND ARC

By P. P. ECKERSLEY, M.I.E.E., F.I.R.E.

This is the first of a series of articles in which the first Chief Engineer of the B.B.C. indulges in what he describes as anecdotage, filling in the background with an account of how the nineteenth century scientists established the foundations upon which pioneering inventors built their systems. In a second article the author will be concerned with the progress of the revolution caused by the invention of the valve, a progress during which he was intimately concerned with the beginnings of broadcasting. He will round off his contribution with some predictions about the future.

I FIRST heard about "wireless" in 1902; Welsh Ethel said "whatever will they think of next I should not wonder." Nannie thought it was flying in the face of Providence; I disbelieved the whole story; how could the signals persist in spite of a thick fog in the Channel?

We called it wireless in those days; in spite of the almost universal adoption of the term radio there are some respectable survivals. "As well," said a pompous young friend, "call a motor car a horseless"; that was more or less what we did call it sixty or so years ago—a "horseless carriage," which was despised by carriage folk. No one despised wireless—it frightened the Cable Interests not the horses.

A fifteen-year-old schoolboy contemporary *circa* 1906 is boasting his acquaintances; turning to me he says "*I* know the man who invented wireless"—he meant, of course, Marconi. By this time I had become passionately interested in the subject of wireless and I replied, sententiously, "No one, not even Marconi, invented wireless."

Try to trace the origins of any important technical development and you will follow a path, getting ever fainter, but often without any obvious end. Wireless, radio, what you will, uses electricity for its consummation. Who discovered electricity? Was it some dry Egyptian priest rubbing a dry cat with a dry cloth? Is this myth of some Greek playing about with amber viable? Can we cite Galvani jabbing at spasmodic frogs, or Cavendish emptying the electric fluid from his jars through his body (also convulsive) as the "onlie begetters"?

In fact it was all these and more: it was the inquisitive experimenters, towards the end of the Middle Ages, breaking away from the domination of the schoolmen; it was these who created the climate in which discovery and invention flourished and may now overwhelm us.

There are, to my way of thinking, four names which prick out the main course of the original development of wireless. They are Faraday, Maxwell, Hertz and Lodge; Faraday and electromagnetic induction, Maxwell and his famous equations, Hertz and his experimental confirmation, Lodge, the one who saw the importance of what he called syntony, what we know as tuning; these established the fundamentals.

It would, however, give an altogether wrong impression to say that these four were the only ones. Even before Faraday we find a few predictions, while contemporary with Hertz and Maxwell was a growing awareness of the possibilities of signalling without wires.

Here is Huygens in 1678 propounding the undulatory theory of light (I always thought the postulate was due to Young in England who got into trouble for challenging Newton's corpuscular theory, but this by the way); Joseph Henry (1843) magnetizing needles at a distance of 200 feet; Ruhmkorff and his invaluable "coil," which we know as "The Induction Coil," inventing one of the essential components of a wireless system long before it was needed for that purpose.

Perhaps the most remarkable among the prophets was Professor R. E. Hughes who, in 1879, gave a private demonstration of the transmission and reception of wireless signals over a path some sixty feet in length. Tragically enough Hughes met with a member of that self-perpetuating species "the inverted Micawbers waiting for something to turn down"; this time a Cambridge professor who told Hughes that his demonstration was no more than a phenomenon of electromagnetic induction. Hughes, discouraged, did no more; he did not even publish his results (could one not wish for a like self-denial in unlike cases?). I underline the date, it was nearly eighty years ago that Hughes gave his (alas!) private demonstration.

In 1885 Edison was convinced that it was possible to signal over short distances without using an interconnecting conductor, he was also explicit on the mechanism which was truly based on electromagnetic induction—not the wireless waves which Hughes had generated and detected. Nevertheless Edison describes aerials earthed at one end—he showed pictures of yachts equipped with such as suitable for this novel means of communication.

In 1892 Sir William Crookes is quoted as saying that "electromagnetic waves of a yard or more in length" will penetrate material impervious to light waves. This implication of the use of the indoor aerial was, however, after Hertz had published his results; results which proved that it was possible to generate waves having the same nature but far greater length than light waves—waves susceptible to reflection, refraction, focusing albeit on a larger scale but fundamentally in the same way as light.

The essential features of what we now call radio are means to transmit and means to receive electromagnetic waves so that the basic inventions cover the generator, the radiator and the detector. Inasmuch as the system would have no value were it not possible to pick up wanted and reject unwanted signals, so tuning stands out as a fundamental necessity. We cannot say that any one person invented wireless but we should give all possible credit to Sir Oliver Lodge who was the first to point out the principles and patent the method for achieving what we now call selectivity.

Lodge's patent "Improvements in Syntonized Telegraphy Without Line Wires" was applied for in May 1897 and granted on February 1st, 1898. Later on the invention was regarded as having such outstanding merit that its life was extended from the normal date of expiry in 1911 by seven years. It was then that the Marconi company bought it.

Still concerned with the pioneers, I believe that had it been possible to create continuous waves as easily as those arising from the damped trains of spark generation then Fessenden's clear appreciation of beat, or as we say heterodyne reception, would have received a wider recognition than in fact it did.

But Marconi, the "inventor" of wireless, how far can he be so acclaimed? There is this to be said in support, that the Marconi patents, remarkably "The Four Sevens," strengthened by Lodge's patent on tuning, did for some time give the company a virtual monopoly of wireless. So much for genesis.

Maybe an incident, maybe some predilection, maybe some inborn and therefore latent talent determines a career. "What's your Alf goin' to be when 'e grows up, Mrs. Blank?" "Oh! 'e's that fond of hanimals we'll make 'im a butcher"—thus *Punch* many years ago.

I am not sure about any latent talent or predilection that I might have had, but like a great many boys, I made inventions (among them perpetual motion), but I doubt I could have followed the career I was driven to had it not been for the influence of my brother T. L. Eckersley. The triggering incident is clear to me still. Returning from school, I was walking up the drive (so steep that we children would suffer dire penalties did we not spare the horses) when standing on the porch steps I saw my brother engaged upon winding startlingly green wire upon a rod of shining black ebonite. My excited question drew the answer: "It's for some experiments with wireless, come and see."

Hardly pausing to receive my mother's affectionate greetings, I hurried upstairs to the Playroom—now no longer rocking-horsed nor doll's-housed—to see it filled with what were at once to me sensually exciting things, things of beauty, fearfully and wonderfully made, black-polished, smooth to the touch, awful in danger, exciting in mystery.

In retrospect, it is remarkable that I became, in the summer of 1905, one of only a few thousands who knew something about wireless. Today tens of millions!

My youth, otherwise "bathed in a celestial light," was illumined by a fascinated interest that even the prison walls has failed to dim: I sometimes wonder whether today's chartered engineers enjoy the same delights.

My brother it was, from an immeasurable height above, who taught me principles and practice. I was, I am still, more interested in the latter, an aspect of incurable romanticism, even in "the first fine careless rapture" I wanted to witness transmissions over distances greater than the compass of the Playroom's forty feet. Was there not talk of bridging the Atlantic by these same wireless waves that were proclaimed by our crackling spark? But brother Tom was more interested in their measurement and the mathematical interpretation of experimental results; a clear pressage of that genius which has now made "T.L." the recognized expert in wave propagation throughout the wireless world.

I went to school at Bedales; a school in many other ways remarkable and, in relation to my story, particularly so in that it encouraged its pupils to indulge such enthusiasms as seemed to authority to be worth encouraging. With this new-found interest in wireless it was not long before Robert Best and I had set up what was, in effect, a wireless experimental station in the school grounds, a station christened by some wag as "Wavy Lodge."

The name was apt because Best supported what was then known as the Lodge-Muirhead system (the counterpoise aerial being one of the distinc-

Photograph taken circa 1907 of Mr. Eckersley receiving signals on a receiver he constructed and installed in "Wavy Lodge," an experimental station set up in the grounds of Bedales School.

tions). In schoolboy rivalry I proselytized the Marconi system, the earthed aerial, in fact. There was no serious clash of opinion between us (it was typical of the Oxford-Cambridge, Harrow-Eton, Blue Fleet *versus* Red Fleet contentions of those days), but it did give our enterprise a certain *cachet* and so made it the easier for us to attract the necessary financial backing from our parents.

From the little hut "Wavy Lodge" (presaging perhaps another hut in a field at Writtle—another story) we transmitted signals and were delighted when these were picked up by the receiver at distances of transmission greater than that over which the spark, generating our waves, was audible; we listened to the grunting of the Eiffel Tower station and experimented with detectors. It was proved that a rusty pair of pliers was a better detector than carborundum (invented by one Dunwoody of Washington, D.C., in 1906), but was rivalled, because of a greater reliability, by a piece of arc-lamp carbon bearing upon a hack-saw blade—slightly oxidized. We also built a wavemeter to a design due to Fleming, who called it a cymometer (from *cyma*, a wave). An accompanying photograph shows the earnest young experimenter, with an expression reminiscent of the H.M.V. dog, supposedly hearing wireless signals rectified by some loose contact embodied in the "Wavy Lodge" receiver.

My *vade-mecum* at this time was Fleming's "Principles of Electric Wave Telegraphy" (first published April, 1906; I still have the 1916 edition). Therein I read of exciting developments in which I longed to participate.

There was the Poulsen arc capable of generating continuous waves, an altogether too expensive and seemingly too dangerous an equipment for schoolboy handling; many high-frequency alternators—Tesla before the turn of the century producing frequencies of 40,000 to 50,000 c/s, Duddell, 1905, Fessenden, Alexanderson, 1908, Goldschmidt, 1912 (200 kW at 50,000 c/s), but all so complex and expensive as to be quite impracticable for amateur use. Among detectors, one of which we bought, the Ferrié electrolytic was exciting. A very fine wire was in contact with an electrolyte; applying a direct potential polarized it, the high-frequency currents broke down the insulating bubble and released current so long as the signals persisted.

A painful recollection is of a despair in getting parental sanction to buy a Marconi magnetic detector and a decision to make one. I was never any good with my hands. I find matter altogether vicious and troublesome. Machinery of all kinds, from electronic complexes to fountain pens, wilts in my presence and so the magnetic detector finished up in a heap of broken bits. In a more serious scientific category (was I not the secretary of the Bedales Scientific Society?) I experimented on the resistance of a loose contact and adumbrated Eckersley's law that the breakdown was equal to the product of mechanical and electrical pressure. Unlike Hughes I published my results, in the Journal of the Bedales Scientific Society.

And so between the fascination of receiving the powerful long-wave European stations—Nauen, Eiffel Tower—(no British station!) and building portable transmitters the years passed until examinations intervened and the sterner facts of life dominated.

I suppose it is fair to characterize this first decade in the practical development of wireless as a failure to make it, because of atmospheric interference, a world communicator, but a triumphant vindication of its powers to link ship and shore and, for military purposes, isolated combat forces with a base. It is also fair to see Marconi as the presiding genius. Marconi was neither a great inventor like Edison nor a great physicist like Sir Oliver Lodge. However, he had quintessentially that rare power to distinguish the wood from the trees. He said in effect "If Hertz can signal across a laboratory I can signal round the world"—in the end he was proved right. Marconi may have done no more than collect the mosaic pieces of invention, due to others, and use them to form his system, but it was this system that held the field and, by its protective inventions, successfully stood up against attacks from all quarters. The "Titanic" disaster in 1912 caused the installation of wireless on ships to be obligatory and it was the Marconi system which was universally installed—some claim with the popular belief that Marconi invented wireless does lie.

"Progress" is, more often than not, due rather to a kick on the backside than a clear foreknowledge of where to go but, whatever the stimulus, it will always be with us. It is my hope that the reader's brief encounter with some of the pioneers, woven into some personal reminiscence, will impress him with the time scale and the astonishing prevision of those men of science, who, interested in discovery as well as invention, so clearly saw the possibility of signalling without wires long before practice made imperfect.

Automation in Marine Navigation

RADAR has brought not only aid to marine navigation but "a variety of complex technical and human problems," said Captain F. J. Wylie in his presidential address to the Institute of Navigation. His address was, he said, "intended to span one of the gaps between bridge and laboratory and to stimulate thought by describing the needs."

Having pointed out that the only positive data which marine radar gives are range and bearing he added "this may seem rather unfair to those who have spent much initiative and energy on the development of true motion radar but it seems better to put the matter in this light because true motion can hardly be regarded as the ultimate ideal, but rather as a palliative which reduces some of the shortcomings of the P.P.I. system of display."

His address posed the question, "Can automation assist the navigator by improving the accuracy and spontaneity of radar intelligence to an extent which will keep him in control of events, and can this be done at a cost commensurate with the advantage gained?" The contributions required from automation are, Capt. Wylie said, "the removal of time lags in assessing the positions and movements of other ships to the point where they become negligible, the reduction of errors to acceptable dimensions and a reduction in the time and mental effort required of the operator to an absolute minimum. In other words, one is merely anticipating a rapid, accurate and effortless means of presenting factual intelligence in the form in which it will be of most use."

Captain Wylie did not enter the controversy in which one view is that radar identification plus radio-telephony can restore all the characteristics of full visibility except to say "the material and human difficulties which militate against 100% success seem to be insuperable."

WORLD OF WIRELESS

Convention on Stereophony

STEREOPHONIC recording, reproduction and broadcasting are to be discussed during a convention being arranged by the Radio and Telecommunication Section of the I.E.E. for March 19th and 20th. The sessions of the convention, which will be held at the Institution, Savoy Place, London, W.C.2, will cover basic principles; stereophonic recording on film, tape and disc; and stereophonic broadcasting techniques. Registration forms and details of the convention, which is open to non-members, are available from the Institution.

Another "Festival of Sound"

G. A. BRIGGS is planning to give his fourth, and, he adds, probably his last, Royal Festival Hall lecture-demonstration on Saturday, May 9th. As in the past, P. J. Walker will be collaborating. The programme will include both live and recorded music and the artists taking part are:—Leon Goossens (oboe), Denis Matthews (piano), Ralph Downes (organ), Harold Blackburn (bass) and Gerald Gover (accompanist).

All seats are price 3s 6d and tickets will be available from Wharfedale Wireless Works Ltd., Idle, Bradford, Yorks., and London dealers after March 16th, and from the Royal Festival Hall on and after April 9th.

Audio Fair

SIXTY-FOUR exhibitors are participating in the London Audio Fair being held at the Russell Hotel, Russell Square, W.C.1, from April 2nd to 5th. Tickets are again being issued free by the organizers, exhibitors and audio dealers, who will have supplies by the end of January. It should be noted that the tickets are dated for specific days.

The Fair, which is sponsored by Audio Fairs Ltd., a non-profitmaking organization set up by manufacturers of audio equipment, will be open daily from 11 to 9, but on the first day admission up to 5.30 is limited to the trade.

National Radio Show.—The success of the Audio Hall introduced at last year's National Radio and Television Exhibition has made it a "must" for this year's show which will be held at Earls Court, London, from August 26th to September 5th. Over a quarter of a million people visited the Audio Hall last year.

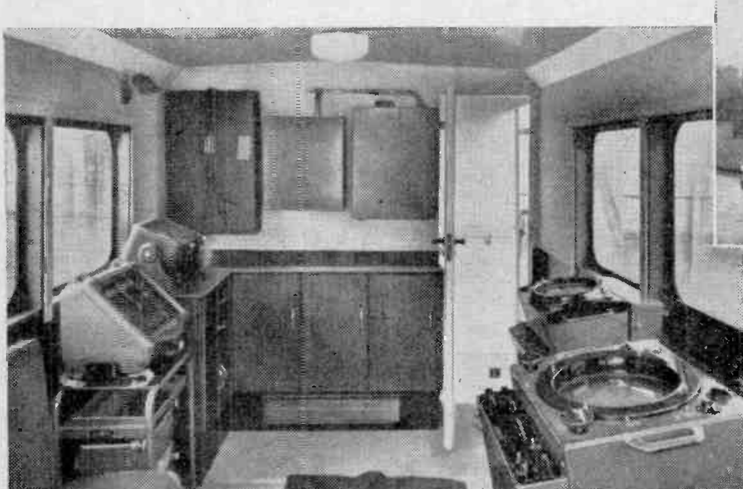
New I.T.A. Channel Allocations.—Although definite allocations have not yet been made, the P.M.G. has stated that it is expected that the I.T.A. satellite station in Kent will radiate in Channel 10. The proposed Aberdeen station is expected to use Channel 9 and the Solway station Channel 11.

Thermonuclear Processes.—The I.E.E. is arranging a convention on thermonuclear processes to be held in London on April 29th and 30th. Particulars of the convention, which is open to non-members, are obtainable from the I.E.E., Savoy Place, London, W.C.2.

Receiving licences in force in the U.K. at the end of November totalled 14,723,953. This total included 8,730,697 combined television and sound licences, 5,627,170 for domestic sound only and 366,086 for car radio.

Instrumentation and Control.—Collaboration in certain major projects for aircraft control and instrumentation systems is provided for in an arrangement covering all aspects of such enterprises made by Smiths Aircraft Instruments and Kelvin & Hughes with the Sperry Gyroscope Co. The first project is the development of a flight control and instrumentation system for new civil aircraft, in particular, the de Havilland 121.

B.S.I.R.A.—A new laboratory block to house its electronics and electro-optics departments has been opened by the British Scientific Instrument Research Association at Chislehurst, Kent.



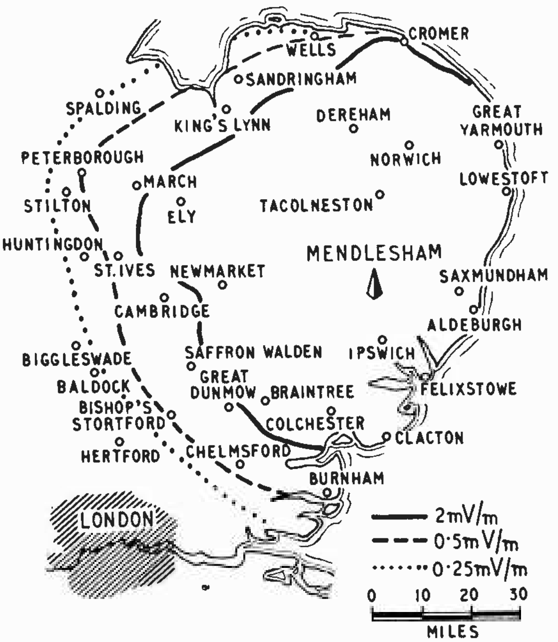
"POLARIS", the new Decca marine radar demonstration vehicle, which this month begins a 6,000-mile tour of Southern Europe, is equipped with two examples of the recently introduced D7 equipment. This series includes three with 9-in displays and four (including two with true-motion) with 12-in displays. The demonstration scanner is mounted on a hydraulic mast for stowage at roof level. The vehicle also carries Decca Navigator and Marine Track Plotter.

Russian Translations.—A modified version of the D.S.I.R. "Translated Contents Lists of Russian Periodicals" is now published monthly under this title by H.M.S.O. It contains lists of translations procured and produced by the D.S.I.R. Lending Library Unit, information about translations available from other organizations, and occasionally articles on the "state of the art" in sections of Soviet science and technology. The annual subscription is £2 13s. The Lending Library Unit has also introduced a new scheme for preparing translations of Russian articles, particulars of which are obtainable from the L.L.U., 20 Chester Terrace, London, N.W.1.

Reliability.—Among the 50 or more papers at the fifth Symposium on Reliability and Quality Control in Electronics held in Philadelphia in January were two by authors from the U.K. K. Hopkinson, of the Ministry of Supply, spoke on reliable valves and performance in Service equipment and L. Knight, of the British Tabulating Machine Co., dealt with economical methods for life testing parts. Ralph Brewer, of the G.E.C. Research Laboratories, Wembley, has received the 1958 National Reliability Award for his paper "Life Tests of Electron Tubes and the Analysis of Failure Causes," which was the only overseas contribution read at last year's symposium.

R.T.E.B. Servicing Certificate.—This year's examination for the radio servicing certificate of the Radio Trades Examination Board will be held on May 5th and 7th (written papers) and May 9th or 30th (practical test). The television servicing examination will be on May 11th and 13th (written) and June 6th or 27th (practical).

Industrial Electronics.—The second of two courses on electronics in industry begins at the Norwood Technical College, Knight's Hill, London, S.E.27, on February 17th. It will be held on six successive Tuesday evenings (fee 10s). The course covers electronic control, industrial television and servo systems.



ESTIMATED COVERAGE of the I.T.A.'s East Anglian station being erected at Mendlesham, Suffolk. It will radiate in Channel 11 when opened toward the end of this year, the transmissions being horizontally polarized. Its maximum vision e.r.p. will be 200kW.

The modulating frequency of four m.f. non-directional aeronautical beacons was temporarily reduced to 400c/s some months ago. It has now been decided by the Ministry of Transport and Civil Aviation to reduce to 400c/s the modulating frquency of all *en-route* and holding m.f. non-directional beacons. The change will be made in the next month or so.

I.T.U. STAMPS.—By arrangement with the Swiss P.T.T., mail despatched from the headquarters of the International Telecommunication Union in Geneva, now bears special stamps. We reproduce one from the series of six.

E.B.U. Technical Centre.—The address of the Technical Centre of the European Broadcasting Union after March 31st will be 32 avenue Albert Lancaster, Brussels, 18.

Welsh V.H.F.—In the note in our January issue on the opening of two new v.h.f. sound broadcasting stations in Wales, the transmitter power and not the e.r.p. of Llanddona was quoted. This station actually uses a directional aerial giving an e.r.p. varying from 3 to 9 kW according to direction. Llanddona's frequencies (in Mc/s) are 89.6 (Light), 91.8 (Third) and 94.0 (Home); Llangollen's frequencies are 88.9 (Light), 91.1 (Third) and 93.3 (Home). These transmitters, and all B.B.C. v.h.f. sound transmitters are horizontally polarized (not vertically as stated last month).

"**Sound,**" the new weekly B.B.C. programme for recording enthusiasts and audiophiles generally, covers both the professional and amateur aspects of recording on tape and disc. The programme, broadcast in Network Three on Mondays at 6.45 p.m. is presented by John Borwick.

Recorded Concert.—A number of manufacturers, including Acoustical, Leak, B.T.H., Decca, E.M.I. and Garrard, are co-operating with Lockwood & Co. to provide a concert of recorded music—including stereophony—on February 27th at Blackwell Secondary Modern School, Headstone Lane, Harrow, Middx. Tickets costing from 2s 6d to 6s 9d are obtainable from Lockwood & Co., Lowlands Road, Harrow, Middx. The proceeds are for the school.

"**The History of Radio.**"—A new colour film strip (35 frames) with this title has been prepared by Mullard primarily for use in secondary modern schools. A comprehensive set of teaching notes is supplied with the strip which is available from Unicorn Head Visual Aids Ltd., 42 Westminster Palace Gardens, London, S.W.1, price £1. A 21-frame coloured film strip on "The Principles of the Cathode-ray Tube," with teaching notes, has also been prepared by Mullard. They are also preparing a strip on the history of television. The Mullard Educational Service has also produced a 16-mm. sound film entitled "Vacuum Practice" which runs for 16 minutes.

British Computer Society, which was formed in May, 1957, with a membership of 450 now has 1,600 members. Two meetings are held in London each month from September to May. The Society issues *The Computer Bulletin* each month and *The Computer Journal* quarterly.

"**F.B.I. Register.**"—The 31st edition (1959) of this register of British manufacturers includes lists of the products and services of over 7,500 member firms of the Federation of British Industries. In addition to the Buyers' Guide there are seven other sections, including manufacturers' addresses, proprietary names and trade marks, and a tri-lingual glossary. The 1,140-page register, which costs 2gns, is published by Kelly's Directories and Iliffe & Sons for the F.B.I.

Personalities

NEW YEAR HONOURS

Among the recipients of awards in the New Year Honours List are the following in the world of wireless:

C.B.

Colonel D. McMillan, O.B.E., director, external telecommunications, G.P.O.

C.B.E.

J. A. Ratcliffe, F.R.S., chairman, Radar and Signals Advisory Board, Ministry of Supply Scientific Advisory Council.

O.B.E.

R. F. Ballard, general manager, Kolster-Brandes.
Dr. L. Essen, senior principal scientific officer, N.P.L.
E. F. Wheeler, superintendent engineer, transmitters, B.B.C.

M.B.E.

A. C. Emery, chief draughtsman, Telecommunications Division, Plessey Company.
G. F. R. Grenyer, station radio officer, Government Communications Headquarters.
W. H. Jarvis, engineer-in-charge, I.T.A. transmitting station at Winter Hill, Lancs.
G. W. G. Martyn, radio officer, s.s. *Argyllshire.*
E. G. Peers, communications officer, London Airport.
R. D. Petrie, head of sound apparatus section, B.B.C. Designs Department.
P. C. Ruggles, senior engineer, English Electric Valve Company.
D. C. Walker, senior executive engineer, Post Office Research Station.
F. R. Warner, in charge of sales (Government contracts) at the G.E.C. Radio Works, Coventry.
F. C. Wells, experimental officer, S.R.D.E.

B.E.M.

F. A. Dann, of No. 4 Ground Radio Servicing Squadron, R.A.F., Chigwell.
A. J. Welberry, technical officer, Post Office Radio Station, Oxford.

J. A. Ratcliffe, O.B.E., M.A., F.R.S., M.I.E.E., who is promoted to C.B.E. in the Honours List for his work as chairman of the Radar and Signals Advisory Board of the Ministry of Supply Scientific Advisory Council, is reader in physics at the Cavendish Laboratory, Cambridge. He was recently appointed chairman for 1958/61 of the U.K. National Committee of the International Scientific Radio Union (U.R.S.I.). He was a member of the Television Advisory Committee from 1949 to 1952, prior to which he was for three years a member of the Radio Research Board.

L. Essen, D.Sc., Ph.D., A.M.I.E.E., who is appointed O.B.E. in the New Year Honours List, has been on the staff of the National Physical Laboratory since 1929. He is in the Electricity Division of the laboratory and has been concerned with precise microwave measurements, in particular with the measurement of frequency and time. Dr. Essen, who is 50, developed a frequency standard based on a resonance of the cæsium atom a few years go.

E. F. Wheeler, M.I.E.E., superintendent engineer of the B.B.C.'s transmitters, operations and maintenance department, who is appointed an O.B.E., has been with the Corporation since 1924. In his present position, to which he was appointed in 1943, he is responsible for the technical operation and maintenance of the Corporation's sound and television transmitters.

R. D. Petrie, A.M.I.E.E., of the designs department of the B.B.C., who becomes an M.B.E., was an engineer with the Gaumont British Picture Corporation before joining the B.B.C. in 1935. Since 1955 he has been responsible for the design of studio and control room equipment and programme switching equipment used in the modernization of the B.B.C.'s sound studios.

P. C. Ruggles, B.Sc., who is appointed an M.B.E., has been with the English Electric Valve Company since its inception, being concerned largely with research and development of microwave valves of national importance. It is for his work in this field that the award has been made.

APPOINTMENTS

K. I. Jones, Assoc.I.E.E., has joined the British Radio Corporation as chief engineer of the H.M.V. and Marconiphone Divisions. He was with Murphy Radio for a few years before joining Cossor in 1932 as chief engineer. He was appointed to the Board of Cossor Radio and Television Ltd., a few months ago. Mr. Jones is a member of the technical sub-committee of the Government's Television Advisory Committee and of the Frequency Advisory Committee recently set up by the P.M.G. He also represents the Radio Industry Council on the B.S.I. Telecommunication Industry Standards Committee and was chairman of the B.R.E.M.A. Technical Committee from 1952 to 1954.

K. I. JONES.

N. J. CHANTER.

N. J. Chanter, M.Sc., D.I.C., A.R.C.S., A.M.I.E.E., for the past 12 years head of the microwave valve division of the Mullard Research Laboratories, has been appointed manager of the transmitting and microwave division of the Mullard Radio Valve Co. He will be in charge of the company's transmitting and microwave valve production unit at Waddon, Surrey, which comprises both the factory and development and applications laboratories.

H. G. Nelson, M.I.Mech.E., M.I.E.E., managing director of the English Electric Company, has also been appointed deputy chairman of some of the subsidiary and associated companies in the group, including Marconi's W.T. Co., Marconi Instruments, Marconi Marine and English Electric Valve Co.

P. J. B. Clarricoats, B.Sc.(Eng.), Ph.D., A.C.G.I., has been appointed to a lectureship in light electrical engineering at Queen's University, Belfast. Prior to taking up his new appointment, Dr. Clarricoats, who is the son of John Clarricoats, secretary of the Radio Society of Great Britain, was engaged on microwave ferrite research with the General Electric Co. at Stanmore.

G. A. Marriott, B.A., who has been with the G.E.C. throughout his professional life, is appointed managing director of the M.O. Valve Co., of which he has been a director for some years. Mr. Marriott was president of the Brit.I.R.E. from 1956-58 and has served on the board of the British Radio Valve Manufacturers' Association (B.V.A.) for many years.

W. H. Stephens, M.Sc., deputy director of the Royal Aircraft Establishment, Farnborough, since 1956, has been appointed to the new Ministry of Supply post of Director-General, Ballistic Missiles. He joined R.A.E. in 1935 and was head of the guided weapons department from 1954-56. He is 45.

S. F. Follett, B.Sc.(Eng.), M.I.E.E., succeeds Mr. Stephens as deputy director of the R.A.E. He joined the electrical engineering department of the Establishment in 1927, at the age of 23, and since 1946 has held various posts in the Ministry of Supply, including that of Deputy Director-General of Aircraft Equipment Research and Development.

J. H. Phillips, B.Sc., M.I.E.E., the new Director, Guided Weapons (Techniques) in the Ministry of Supply, was a scientific officer at the Bawdsey research station (forerunner of the Royal Radar Establishment) in the early days of the war. Since 1957 Mr. Phillips, who is 49, has been with the British Joint Services Mission in Washington, prior to which he was for six years at the headquarters of the Guided Weapons Research and Development Department of the M.o.S.

Four new engineering appointments are announced by the B.B.C. **R. A. Rennie,** who has been with the Corporation since 1941, becomes engineer-in-charge (sound) at Glasgow in succession to J. G. W. Thompson who has retired. **L. M. Robertson** takes up the post of e.-in-c. of the new television and v.h.f. sound station at Orkney. He joined the B.B.C. in 1943. **J. S. Clemo** becomes e.-in-c. of the Rosemarkie television and v.h.f. sound station in succession to M. Clough, who recently became assistant e.-in-c. at the high-powered station at Holme Moss. **M. Taylor,** A.M.I.E.E., succeeds J. P. McCurdy (who has retired) as e.-in.-c. of the Lisnagarvey medium-wave transmitter. Mr. Taylor joined the Corporation in 1936 and was seconded to the Forces Broadcasting Service in the Middle East in 1948, and for two years (1951-53) was chief engineer of the Colonial Broadcasting Service in Cyprus.

F. L. Firth, B.Sc.(Eng.), engineer-in-charge of the recently opened I.T.A. station at Burnhope, Co. Durham, was a chief radio officer in the Merchant Navy during the war. Prior to joining the I.T.A. in 1956 he was with Ferranti's where he was engaged on test gear development and eventually took charge of an experimental test laboratory.

P. D. Hall, B.Sc., M.I.E.E., has been appointed manager of Ferranti's computer department following the resignation of **B. W. Pollard.** Mr. Hall, aged 39, joined the company in 1951 as a senior electronics development engineer and was appointed manager of the electronics department in 1955. **J. R. Pickin,** B.A.(Hons.), aged 31, who was formerly chief engineer working on microwave devices, succeeds Mr. Hall as manager of the electronics department.

P. D. HALL.

J. R. PICKIN.

A. S. Marshall has been appointed to the new post of deputy secretary of the Electronic Engineering Association. He recently retired with the rank of Lt. Commander from the Royal Navy, which he joined in 1937 having previously been in the Merchant Service for over 20 years. He was at one time in the Admiralty's Radio Equipment Department and more recently the Admiralty Research Laboratory at Teddington.

A. S. MARSHALL.

F. H. Townsend, M.I.E.E., who in 1957 resigned from the managing directorship of Cathodeon Ltd., and went to America to take up an appointment with Machlett Laboratories Inc., of Springdale, Conn., has now joined Westinghouse. He is in charge of engineering on Vidicons and similar types of tube at the Westinghouse Electronic Tube Division in Elmira, New York.

V. G. Hawkeswood has joined Southern Television, the programme contractors for the I.T.A. Chillerton Down station, as head of engineering. He was for 22 years with the B.B.C. and since January, 1955, had been engineer-in-charge of television in the North Region.

E. M. Butterworth has been appointed chief engineer of Besson & Robinson Ltd., relay manufacturers of Harlow, Essex. He was until recently chief development engineer with Magnetic Devices Ltd.

OUR AUTHORS

L. A. Moxon, B.Sc., A.M.I.E.E., whose articles on evaluating aerial performance start in this issue, studied electrical engineering at the City and Guilds Engineering College, obtaining his London University degree in 1929. After two years' research under a D.S.I.R. grant, he joined the staff of Murphy Radio and was responsible for radio receiver research and development. In 1941 he joined H.M. Signal School, Portsmouth, and is now a member of the Royal Naval Scientific Service. He has held an amateur transmitting licence since 1929.

J. F. Young, A.M.I.E.E., A.M.Brit.I.R.E., who contributes the article on page 92, served an apprenticeship with the G.E.C. at Witton, afterwards working on the development of closed-loop control systems. He then spent some time with W. & T. Avery and Lancashire Dynamo Electronic Products on industrial electronic development, and subsequently returned to Witton to take charge of the Electronic Development Group of the Switchgear Works.

OBITUARY

R. Moxham, manager of the G.E.C. factory at Broad Oak, Portsmouth, where precision electronic work for defence is carried out, died on Christmas Day at the age of 50. Mr. Moxham joined the G.E.C. in 1933, and in 1939 was appointed chief inspector of the Radio Communications Group at Coventry. During the war he was engaged in major work on the development and production of v.h.f. equipment for the R.A.F.

Dipl.-Ing Eugen Reinhard, who died recently aged 82, was responsible for the erection of the Norddeich and Nauen transmitters in 1906. From then until 1932 he was responsible for building most of the important Telefunken stations in all parts of the world.

Evaluating Aerial Performance

1.—Simplified Method of Calculating Gain and Radiation Resistance of Dipoles and Small Beam Arrays

By L. A. MOXON, B.Sc. A.M.I.E.E

IN any given practical situation, what is the best type of aerial to use? The answer to this question is not always obvious, especially if the problem happens to be one of television reception in a difficult area, or achieving the best possible performance on the amateur wavelengths. In the latter case the need to cover all directions on several frequency bands, coupled with space restrictions or other peculiarities of the local terrain, gives rise to a wide variety of interesting problems. Despite the existence of excellent handbooks, the student may well find difficulty in acquiring a clear overall picture of the subject from published material. In particular he may be confused or led astray by conflicting figures for the gain of simple types of beam aerials, failure to make clear distinctions between the requirements for transmission and reception, misplaced emphasis on front-to-back ratio and standing-wave ratio, and a widespread belief that vertical aerials and some beam arrays provide signal enhancement, in addition to their nominal gain, if any, by "lowering the angle of radiation." He will almost certainly be intrigued by references to the "super-gain" principle, but unless he is mathematically inclined this subject is likely to remain veiled in mystery.

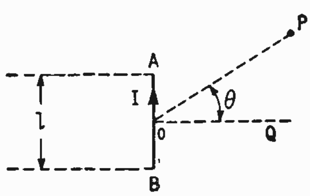


Fig. 1. Current I flowing in wire AB of length l produces field at P which is proportional to Ilcos angle POQ. AB is assumed small compared with a wavelength and OP is large compared with AB. Maximum radiation is in the direction OQ at right angles to AB.

In discussing these various aspects of aerial design it is hoped to show that most problems outside certain highly specialized fields can be tackled with no more equipment than a few elementary rules, common sense, and simple arithmetic. It will be shown that one can, from the construction of an aerial, arrive quite easily at a rough figure for its probable gain and thus be enabled to discount extravagant claims, or to check the results of measurements against "what is reasonable" before either discarding some new arrangement as unsatisfactory or becoming unduly enthusiastic about it. This seems particularly important in view of the many problems involved in the making of accurate measurements, as discussed in previous issues of this journal.[1]

The super-gain principle will be shown to have a simple physical basis which enters into the operation of all close-spaced beam aerials including the familiar H.

Radiation from Dipoles.—Any aerial system can be regarded as made up from a number of doublets, i.e. short lengths of wire each carrying a uniform current, which may be either separate or joined together. When used for transmission each such length makes a contribution to the field strength at a distant point, such as P in Fig. 1, in accordance with the following rules. These state that the field is proportional to the current I, the length of wire through which it flows, and the cosine of the angle θ. Non-mathematical readers may be alarmed at the introduction of a cosine at this early stage in the argument, but in many cases the problem can be reduced to one of arithmetic by considering only a few angles such as 30°, 45° and 60° for which the field is respectively 0.87, 0.7 and 0.5 times that at right-angles to the wire. Below 30° the field is roughly proportional to the angle POA and can often be ignored since it accounts for only a very small proportion of the power radiated, no less than 82% of this being within ±45° of the direction OQ. Later these facts will be used to obtain a rough idea of the radiation pattern of simple beam aerials, leading to estimates of gain, radiation resistance, and front-to-back ratio.

A doublet as in Fig. 1 bears little resemblance to a practical aerial, so let us see what happens as the wire is increased in length and the current distribution allowed to approach a half sinewave as in Fig. 2, which represents the conventional half-wave dipole. The non-uniform current distribution presents no difficulty since we merely have to imagine the wire divided up and the contributions of all the bits added together, which is the same thing as finding the average current and multiplying it by the total length. The current distribution in a half-wave dipole can be taken as roughly sinusoidal, which means that it has an average value 0.64 times the current in the centre.

So far the theory assumes that whatever the direction of P, the radiation from all the bits of the dipole can be directly added. This is not true if one

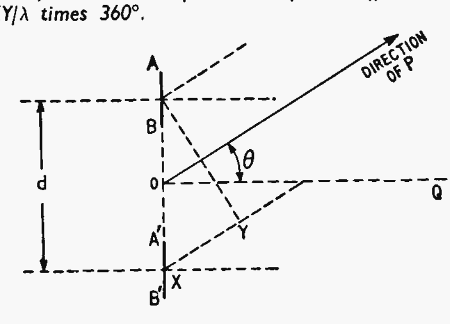
Fig. 2. Approximate current distribution in half-wave dipole. With shortened dipole (as Fig. 7) the portion bc of the sine wave occurs in the feeder and the remaining portions ab, cd form a nearly-triangular distribution.

considers bits which are separated by an appreciable fraction of a wavelength, as illustrated in Fig. 3. In this case the radiation adds in phase when the direction of P is at right angles to the line joining the centres of the wires, but for other directions there is a difference of path length, and a corresponding phase difference. This causes the radiation to decrease more rapidly with angle thus tending, for moderate values of d, to concentrate the radiation in the normal direction. In the case of the half-wave dipole, in free space, i.e. ignoring effects due to the presence of the ground or other objects, radiation from near the two ends, for small values of angle AOP, cancels because the path difference is nearly half a wavelength. In these directions, however, the radiation would be infinitesimal in any case, and it can be seen that for the central portion of the dipole and directions within $\pm 45°$ of OQ, which account for most of the power radiated, phase differences are quite small. This means that, as illustrated in Fig. 4, a half-wave dipole produces almost the same field-strength pattern as an infinitely short dipole radiating the same power. Such an aerial could not be achieved in practice, but the conclusion is very useful since it means that each $\lambda/2$ dipole or " current loop " in an aerial array can be treated (to a first approximation) as a point source, and this in turn simplifies the procedure for estimating the field pattern of aerial arrays.

We have seen that there is no basic necessity for making dipoles half a wavelength long, but this length usually provides a reasonable compromise between conflicting mechanical and electrical design factors. In addition it has the advantage of presenting a resistive impedance at the feed point so that direct matching to a non-resonant line can be achieved without the introduction of tuning reactances. When, for example, space or weight is at a premium, some shortening is permissible but leads, as will be seen in due course, to a narrower bandwidth, and more critical matching and tuning, and eventually to a loss of efficiency. The laws governing the transmission of power from the aerial to a receiver at P apply equally to the reception of power from a transmitter at P, but in reception the important quantity is signal-to-noise ratio and, as discussed later, this is not always directly related to the received power.

Radiation Resistance and Loss Resistance.—When radio-frequency power is applied to an aerial some of the energy is radiated and some of it is used in heating the wires and insulators of the aerial system. In the case of a half-wave dipole, a current of 1A in the centre results in the radiation of 73 watts, and the aerial is therefore said to have a radiation resistance of 73 ohms. In principle, radiation resistance can be defined for any point in an aerial system by equating I^2R_r to the power radiated, where I is the current and R_r the radiation resistance at the point in question. In the above example there is, of course, no actual resistance carrying a uniform current I, and it is therefore usual to regard radiation resistance as a mathematical fiction. On the other hand, from a practical point of view the aerial behaves as if the resistance is real, and the power radiated must eventually be absorbed by resistance somewhere even though some of it may escape into outer space and travel a very long way before this happens. It seems arguable, therefore, that the aerial should be regarded as a kind of transformer inserted between the transmitter and a somewhat intangible network of load resistances, R_r being real but dependent, of course, on the " transformer " ratio. This concept is useful in dealing with noise problems since it helps to dispose of the common error of regarding R_r as a generator of thermal noise at local temperature. The noise voltage at the aerial terminals may or may not be of thermal origin[7] but is in any case a property of " where radiation from the aerial would get to " and is usually represented by a voltage or " temperature " associated with R_r.

Fig. 3. Radiation from the dipole A'B' towards P has to travel a greater distance than that from AB. The difference is XY, or dcosθ and produces a phase difference (α) of XY/λ times 360°.



The high-frequency resistance of the aerial wire may be estimated from Fig. 5 and comes to 1.3 ohms for a typical $\lambda/2$ dipole (0.1-in diameter wire) at a frequency of 14Mc/s. To find the power lost in the aerial it is necessary to multiply this resistance by the mean square current which, for a sinusoidal current distribution, is only half the value which was assumed to be flowing into the radiation resistance. For comparison, therefore, with the radiation resistance the loss resistance has to be divided by two and we thus find that the ratio of power radiated to total power is 73 to (73 + 0.65), i.e. more than 99% is radiated. Some additional loss may occur in insulators (if used), and in the feeder system as discussed later.

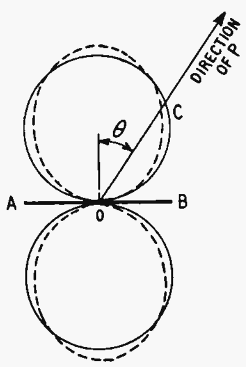


Fig. 4. Field-strength pattern of dipoles. The relative fields at P, when this point is moved round the dipole at constant range, is given by the length OC. With λ/2 dipoles the pattern consists of two circles, or near circles (broken line)

Short Dipoles.—It is instructive to consider what happens if the length of the dipole is halved, keeping the radiated power constant. We have already seen that this process leaves the way in which the energy is distributed in space almost unchanged, and therefore the field strength at any point P is unchanged. It follows that the product of length and mean current must be the same, so that the mean current must be double what it was before, and for a given shape of current distribution the radiation

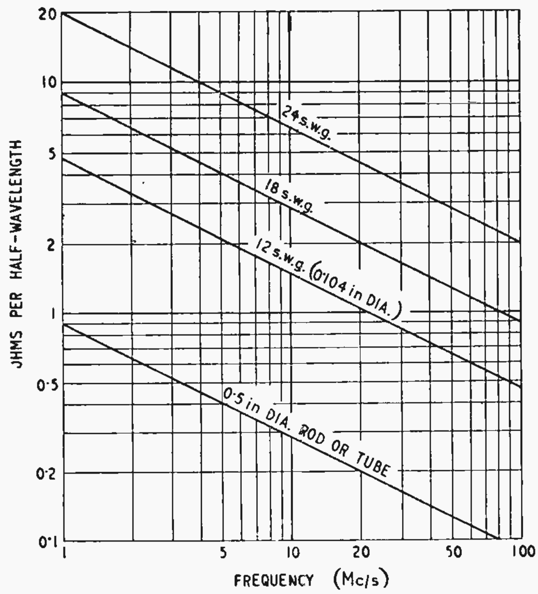


Fig. 5. R.F. resistance of copper conductors. Resistance per unit length is proportional to $\sqrt{frequency}/(perimeter\ of\ conductor)$, provided thickness of conductor is large compared with skin depth which is approximately $0.007/\sqrt{Mc/s}$ (in cms). For non-magnetic materials r.f. resistance is approximately proportional to $\sqrt{specific\ resistance}$.

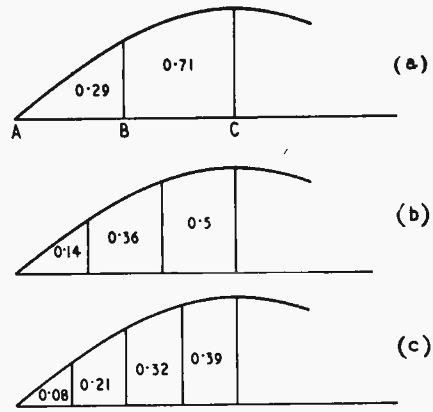
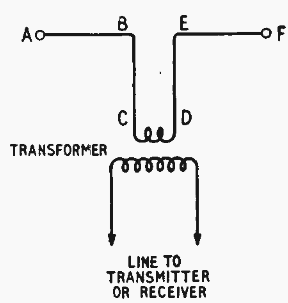


Fig. 6. Relative contribution of various segments of a sinusoidal current distribution to the total field strength.

resistance is reduced by a factor of four whereas the loss resistance is only halved. In practice the situation is worse than this for two reasons. In the first place, the current distribution is no longer a complete sinewave but just the tips of one, which makes it nearly triangular; the effect of this can be estimated from Fig. 6(a) which shows that the end portion AB contributes 29% of the total field of a $\lambda/2$ dipole. To obtain the same field as from a $\lambda/2$ dipole therefore, we have to increase the current at B from 0.71 to $0.71 \times 1/0.29$ or 2.45 times the current at C. This makes the radiation resistance equal to $73/(2.45)^2$ and thus brings it down to 12.1 ohms. Secondly, the impedance in the centre is now highly reactive, and the reactance must be tuned out in order to match the aerial to the transmitter. One way of doing this is to construct the short dipole by folding a half-wave one as shown in Fig. 7. It is convenient to retain CD, the original centre of the dipole, as the reference point so that if the current distribution from A to F via CD remains sinusoidal the current at CD will be $\sqrt{2}$ times the current at BE and the radiation resistance only 6.05 ohms whereas the effective loss resistance remains very roughly at 0.65 ohms as in the half-wave case. The power wasted is now nearly 10% or a loss of about 0.4dB, which begins to be appreciable when added to the further small loss of 0.4dB for a short dipole, relative to a $\lambda/2$ dipole, as indicated in Fig. 4. In a given practical situation other factors may come into the picture; for example, since there is less length to support the adverse effects of shortening may be offset by the possibility of erecting the aerial at a greater height or of using thicker diameter conductors. This illustration is probably near the lower limit of size for an efficient transmitting aerial since the losses increase rapidly with further shortening; for example, a further halving of the length will reduce the radiation resistance at CD (Fig. 7) by a factor of 16 to only 0.4 ohms which would entail both poor efficiency and serious matching difficulties. As we shall see, this situation becomes much worse if the dipole forms part of a beam aerial system, and the shortest acceptable length is then correspondingly increased.

The argument has been simplified by ignoring certain effects caused by the discontinuity at BE. In general, these tend to increase the length of wire required for resonance, but leave the losses more or less unchanged. The portion BE-CD can of course be replaced by loading coils but, due to the proximity effect, i.e. eddy currents induced in each wire by adjacent wires, coils tend to have a lower Q than a high-impedance transmission line such as BE-CD, and the losses are therefore higher. Another important consequence of shortening is the reduction of bandwidth. A rough estimate of this can be

Fig. 7. Short dipole loaded to resonance by open-wire transmission line BE-CD. Inductance of transformer winding CD is neglected.



made quite easily. Suppose we have a resonant line, one quarter-wavelength long and open-circuited at the far end, as sketched in Fig. 9. If there are no losses the impedance measured between A and B will be zero, but if the length is changed by a small amount, $\pm b$ of a wavelength, a reactance of $\pm Z_0 \times 2\pi b$ ohms will appear at the terminals, Z_0 being the characteristic impedance of the line. Opening the line out to form a half-wave dipole involves no change of principle, although in typical cases it involves an increase of about 50% in Z_0; this, incidentally, is the reason for the change in resonant frequency which occurs when the line is only partly opened out, as in Fig. 7, the reactance subtracted by shortening the radiator being 50% more than that added in the form of the resonant line BE-CD. The change in length, b wavelengths in a $\lambda/4$ line, is equivalent to a change of $4b$ times 100% in frequency so that the bandwidth of the aerial (defined by analogy with that of a tuned circuit) may be found as follows. We first obtain the "3-dB down" points by equating resistance and reactance, i.e. $2\pi bZ_0 = R_r$ so that b is given by $R_r/(2\pi Z_0)$. The separation of the two "3-dB down" points, as a fraction of the mean frequency, is therefore given by $8b$ or $(4/\pi) \times (R_r/Z_0)$. Z_0 varies in practice from about 400 ohms for a short, thick v.h.f. dipole to 1,100 ohms for a thin wire h.f. dipole, being

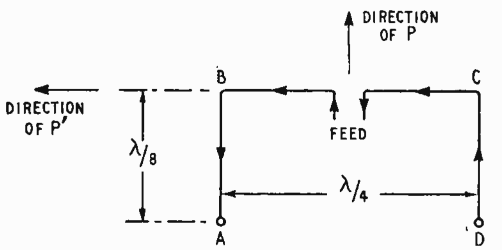


Fig. 8. Example of bent λ/2 dipole. Arrows indicate current flow.

equal to 276 $\log_{10}$ (2 × length/diameter) − 120. (Ref. 8). For a typical "wire" dipole on Channel 1 (45Mc/s), we find a bandwidth of about $(4/\pi) \times (73/900) \times 45$ or 4.6Mc/s which is reasonably adequate but allows very little margin to cope with, for example, the reduction of bandwidth which would follow the addition of a reflector.

Since a half wavelength of line is equivalent to a 1 : 1 transformer the total length of the system could be increased from a quarter to three-quarters of a wavelength by adding feeder, but a given small percentage change in frequency would then change the effective length by three times as much and ignoring the change of Z_0 the bandwidth would be reduced by a factor of three. To sum up we find that shortening a dipole results in increased losses and reduced bandwidth in much the same proportion. These effects are aggravated by using resonant feeders, being roughly proportional to the total number of current loops in the system. A quarter-wave dipole would of course be quite useless for television, but is "broad band" in another sense, since with narrow-band signals it can be used efficiently over a wide range of frequencies subject to adjustment of tuning and matching whenever the frequency is altered.

We have seen how Fig. 6 enables the radiation resistance of dipoles to be estimated for a sub-harmonic of the resonant frequency, and intermediate lengths can be dealt with by interpolation. Fig. 6 can also be used to deal with the case of dipoles bent into odd shapes such as Fig. 8, which shows what might have to be done to a 14-Mc/s or 7-Mc/s dipole in order to make it fit into the width of a typical suburban garden; to evaluate this situation, suppose we have available a power W which produces a current I in a normal dipole. Let E be the field strength which this would produce at some point P. From Fig. 6(a) the same current in the bent dipole of Fig. 8 will give rise to a field strength 0.7E due to the current in BC; this corresponds to a radiated power of W/2 only. The currents in AB, CD produce fields which cancel at P but, due to the $\lambda/4$-separation between AB and CD, add up in phase quadrature at P′ to give a field $\sqrt{2} \times 0.3E$ which at first sight corresponds to a radiated power of 0.18W, but AB and CD on their own would constitute a beam aerial of the "8JK" type which, as described later, has a gain of 2.5 times. The radiation from AB, CD therefore corresponds to a power of only 0·18/2·5 W, i.e. 0.072W. The total power radiated is therefore 0.572W, so that for radiation of a power W the current increases to a value $I/\sqrt{0.572}$. This means that the radiation resistance is down to 57.2% of 73 ohms, i.e. 41.8 ohms which is still a reasonably high value, and the field strength at P is reduced by only $\sqrt{50/57.2}$ or about 0.6 dB as compared with that from a normal dipole. What may at first sight have appeared to be an abstruse mathematical problem has thus yielded to a mixture of common sense and arithmetic, but with some loss of rigour since at intermediate angles the field due to BC is slightly modified by radiation from AB, CD and this in turn will have a small effect on the radiation resistance.

When adding the radiation from two or more dipoles, due account must be paid to differences not only of phase but also of polarization. When radiation takes place from a wire, the electric vector of the wave is parallel with the wire, and radiation from a vertical and a horizontal dipole adds in quadrature.

Power Gain.—The majority of aerials are non-isotropic; this means, in terms of transmission, that they do not radiate the same amount of power in all directions. It follows that relative to an isotropic aerial radiating the same total power, they provide a gain in some directions and a loss in others. Ignoring for the moment effects due to the ground, i.e. assuming the aerial to be located in "free space," its gain and radiation pattern can be obtained from its geometry provided the relative magnitudes and phases of the currents flowing in the various parts of the system are known. The main essentials of the method have already been used to prove the near equivalence between a half-wave dipole and a short dipole. The same procedure can be applied to any number of aerial elements and used to obtain a complete radiation pattern, and hence the gain which is simply the ratio of the power radiated in the desired direction to the power averaged over all directions. Calculation of gain in this way is simple enough in principle, but laborious in practice, and it is tempting to look for a short cut. It has already been remarked that most of the energy is radiated between the "3-dB down" directions, and there is an obvious analogy between beam width of aerials and bandwidth of filters which provides encouragement for the idea of estimating gain from a simple comparison

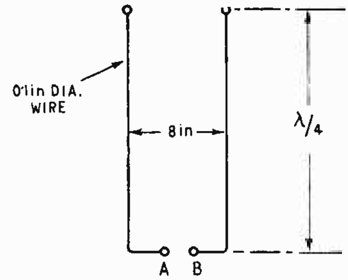


Fig. 9. Typical resonant line (Z_0 = 600Ω). If length is changed by a small fraction b of a wavelength, or the frequency by 4b × 100% a reactance $2\pi b \times Z_0$ appears at AB.

of half-power beam widths. This is only admissible if the lobes which are being compared are similar in shape and account for most of the energy radiated, conditions which seem to be reasonably well satisfied with typical small beam aerials, although corrections are necessary in the case of more elaborate systems.

In the case of a receiving aerial in free space, it is plausible to suppose that the space in its vicinity is uniformly filled with signal energy so that the greater the volume occupied by the aerial, the more energy can be collected. The energy available in a given volume of space can be estimated from the field strength, and collected by filling the volume with dipoles connected together in such a way that the induced voltages are added in phase. In this way we arrive at the result that with a large array of elements the gain is proportional to the volume occupied. This is a useful concept but may need modifying to take account of multi-path and diffraction effects, or the presence of the ground, which can produce a non-uniform field distribution. Also, as will be seen, it is possible by introducing phase differences to obtain larger as well as smaller gains.

Another approach is to consider transmission from a pair of dipoles arranged so that their fields add in phase in a desired direction. If these are close together, appreciable power will be fed from one into the other; in other words there is mutual coupling, and the current in one will affect the current in the other, but for the moment let us imagine that the dipoles are far enough apart for this effect to be neglected. Suppose that a total power W is available which, when applied to a single dipole, produces a current I and in consequence of this a field E at some distant point P. If now this power is shared equally between the two dipoles, each will produce a field strength $E/\sqrt{2}$ and these fields added in phase give $2E/\sqrt{2}$, i.e. $\sqrt{2} \times E$ which represents a power gain of 2 times, or 3dB. Extending this argument to N dipoles gives a power gain of N. The requirement of adequate spacing means that the volume occupied by the array tends to be proportional to N, so that once again we find gain proportional to volume, but with the added proviso that it cannot exceed N. To establish this relation in numerical terms, it remains necessary to find the minimum allowable spacing between elements; this can be done with the aid of published tables of mutual impedance, but it is instructive to return to the geometrical approach, and Fig. 3 provides a good example of this. Half a wavelength is a convenient value for *d* since with half-wave dipoles it brings A′ and B together and allows them to be fed from a single feeder, so let us investigate the gain under these conditions.

For any value of θ, the distance XY can be determined either graphically as shown or from the relation $XY = d \sin \theta$. Expressing XY in wavelengths, it can be multiplied by 360 to obtain the corresponding phase shift in degrees, and the field produced at P can be obtained by graphical addition as shown in Fig. 10 or, if $E_1 = E_2$:—

(from the formula) $E_P = 2E_1 \cos \alpha/2$

If θ is 30°, XY is $\lambda/4$, $\alpha = 90°$, and $E_P = \sqrt{2} \times E_1$, which represents a 2 : 1 drop in power compared with direct addition of the two voltages.

It is also necessary to allow for the directional properties of the individual dipoles, which, as already discussed, reduce the field by 13% at 30°. The beam width between half-power points is therefore slightly less than 60°, and the gain compared with a half-wave dipole, based on the ratio of half-power beam widths, is therefore slightly more than 90/60, or 1.5 times. More precise calculations give a gain of 1.6 times, the gain being less than 2 because of mutual interaction between the elements which can be estimated as follows: if R'_r is the effective radiation resistance of each element, and I the current, the power radiated is $2I^2R'_r$. For a single dipole, with current I_D and radiation resistance R_r, the power radiated is $I_D{}^2R_r$. With no interaction, $R_r = R'_r$ so that for equal powers in the two cases $I = I_D/\sqrt{2}$ and, as we have seen, there is a gain of 2. If the gain is less than this, the current must also be less, otherwise we should fail to satisfy the condition that the field strength is proportional to the mean current multiplied by the length of wire through which it flows. In this case, therefore, the current is less than $I_D/\sqrt{2}$ by the factor $\sqrt{1.6/2}$ and R'_r must therefore be equal to $(2/1.6)R_r$. For a pair of half-wave dipoles, therefore, R'_r becomes 73/0.8= 93 ohms, so that the proximity of one element increases the radiation resistance of the other by 20 ohms; in other words there is a mutal resistance of +20 ohms. This example demonstrates the interdependence of gain, beam width, radiation resistance, and mutual impedance, and shows that any one of these quantities can, in principle, be used to obtain the others; in particular, given the mutual resistance as a fraction of the radiation resistance the whole example could be worked backwards and the

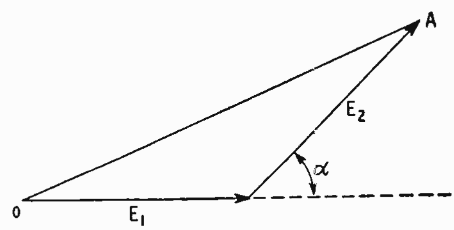


Fig. 10. Vector addition of two fields. E_1 represents field at P due to element A′B′ of Fig. 3. E_2 represents (same scale) field due to A′B′. Angle α is the relative phase of the two fields and is equal to 360° x d/λ $\cos\theta$. The field strength at P is proportional to length OA. Similar procedure is applicable to any number of field components when relative magnitudes and phases are known.

gain calculated exactly. In the case of beam width, however, the augument rests on rather crude assumptions and should not be applied too literally.

The case of a broadside array, Fig. 11(a), can be treated in a similar way except that the radiation pattern differs from that of the dipole in both horizontal and vertical planes and must therefore be estimated for both. In this case we obtain the interesting result that the gain is *more* than two; in other words the mutual impedance can increase the gain as well as reduce it, and in large arrays of dipoles spaced by $\lambda/2$ such effects are likely to even out so that the gain tends to N approximately. In general, for collinear and end-fire elements spaced $\lambda/2$ the gain is between 1 to 2dB less than N, and for broadside elements about 1 to 2dB more than N. Large systems of this kind are unlikely to concern the non-professional reader, but the principles apply equally to small beam aerials such as those used for amateur communication or for TV reception. These are mostly of the end-fire variety (Fig. 11(b)), using two or more $\lambda/2$ elements with spacings between about $\lambda/8$ and $\lambda/4$. Assuming two such elements and working out the radiation pattern and gain as for the collinear elements, but introducing a phase shift between the currents, some interesting facts emerge. The maximum gain is relatively large (nearly 4 times), no longer coincides with in-phase addition of the two fields in the desired direction, and is critically dependent on the phase shift, being a maximum when the currents are nearly out of phase. Remembering that the dipoles can, in principle, be as short as we like to make them, and have in fact been assumed short for purposes of calculation, we reach the conclusion that an aerial of small dimensions is able to collect the signal energy from a relatively large volume of space.

At first sight this may seem contrary to nature, and to reconcile it with previous concepts requires a new physical picture; this can be obtained by going back to first principles and restating the purpose of the exercise, which is to concentrate the energy in the desired direction at the expense of others.

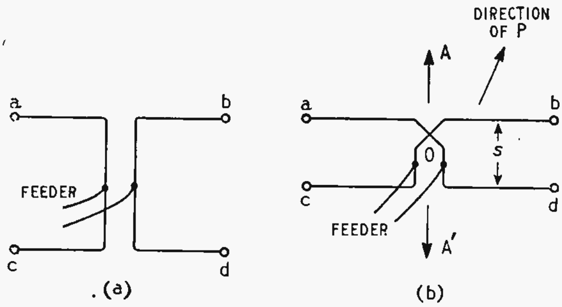


Fig. 11. With a broadside array (a) elements ab, cd are fed in phase. Maximum radiation takes place in direction at right angles to plane of the paper. "End-fire" array (b) is of the "8JK" type and elements are fed anti-phase and maximum radiation is in directions OA, OA'.

This can be done either by making the fields add up in the desired direction as already described, or by making them cancel each other in the undesired directions. To make them add in one direction but not in others it is necessary, as we have seen, to have large aerial dimensions so that a small departure from the wanted direction produces substantial differences in path length for the different elements and corresponding phase shifts. With the second approach, however, there is no lower limit to the spacing; if the elements are close together, cancellation of fields in one direction obviously means near cancellation in all others, but this does not restrict the radiation of energy which is concentrated in the directions for which cancellation is least effective, for the simple reason that there is nowhere else for it to go. Since, however, the actual field is the difference between nearly equal and opposite fields, it follows that the element currents must be large, the radiation resistance and bandwidth small, and the situation analogous to the case of a high-Q circuit which is able to extract all the available energy from (or deliver its energy to) another circuit to which it is only very loosely coupled.

This can be understood more clearly by a simple example. Consider a horizontal end-fire array of two closely spaced elements, as in Fig. 11(b), with the elements fed in opposite phase. This arrangement is well known in amateur radio circles as the "8JK" aerial. Radiation in the upward and downward directions is zero, but in the directions OA, OA', cancellation is incomplete because of the phase shift ($s \times 360°$, where s is measured in wavelengths). In a direction such as OP radiation is reduced in the normal way by $\cos\theta$ where θ= angle POA and also by as much again because, viewed from P, the elements appear to be closer together by this amount. We thus have radiation patterns given by $\cos^2\theta$ in the horizontal and $\cos\theta$ in the vertical plane. Putting $\cos^2\theta = 1/\sqrt{2}$ we have (for the half-beam widths) $\theta = 32°$ so that as compared with a dipole, the horizontal lobes are narrowed in the ratio 32/45 and the vertical pattern is narrowed from 360° to a total of 180° from which we might expect a power gain of 90/32 or 4.5dB.

Once again we find that this method of calculating gain, crude though it is, has given an answer very close to the right one (4.2dB), but the main point to note is that the calculation *takes no account of the length or spacing of the elements and the gain is therefore independent of the physical size of the aerial system*, provided, of course, the dimensions are not too large and that the losses are constant or negligible.

Let us now assume some values for current, say 1A in each element, and spacing, say $\lambda/8$ which produces a phase difference ϕ_o in the line-of-fire of 45°. Since we start with the currents 180° out of phase, this makes α, Fig. 10, equal to 135° and putting $E_1 = E_2 = 1$ we find that OA is only 2 sin $22\frac{1}{2}°$ or 0.76. In other words the field produced is no greater than could be obtained by a current of 0.76A flowing in a single dipole. We now know, however, that the field strength is 4.2dB, or 1.6 times in voltage, greater than that produced by a dipole, so that the same power applied to the dipole would result in a current of only 0.76/1.6 or 0.475A. To obtain the radiation resistance R_r for each element, therefore, we have to equate $2 \times 1^2 \times R_r$ to $(0.475)^2 \times 73$, which makes R_r only 8.1 ohms. Halving the spacing would call for twice the current and bring the radiation resistance down to only about 2 ohms, the bandwidth being now very narrow and the losses probably serious. As this process is continued, the point is reached where a small inequality in the currents produces a larger out-of-balance component than does the phase shift, and the radiation pattern then reverts to that of a dipole. The allowable inequality is directly proportional to spacing and would appear to be in the region of 10% to 20% for a separation of $\lambda/8$. Halving the length as in Fig 7 would bring the radiation resistance down by the same ratio as in the case of the single element, i.e. from 8.1 to 0.7 ohms.

With two modifications, the "8JK" aerial can be converted into a conventional H aerial. Let it be supposed that the current in the lower element of Fig. 11(b) is given a phase lag equal to ϕ_o; for the direction OA' the phase shift is now $\phi_o - \phi_o$, i.e. zero, and there is no radiation, whereas for the direction OA the phase shift is $2\phi_o$, the field for a given current is twice what it was for the "8JK" arrangement, and the beam is now unidirectional with an infinite front-to-back ratio. As θ varies, the phase shift varies as $(\phi_o + \phi_o\cos\theta)$ instead of

(*Continued on page 65*)

as $\phi_0 \cos\theta$, so that the forward pattern is now broader. This, together with some radiation upwards and downwards, accounts for the energy previously radiated in the direction OA′, and the gain is more or less unchanged. Because the phase shift is doubled, however, the radiation resistance is four times as large, accurate balancing of the current amplitudes is less important, and parasitic excitation of one element from the other, as in the H array, is acceptable.

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(To be concluded.)

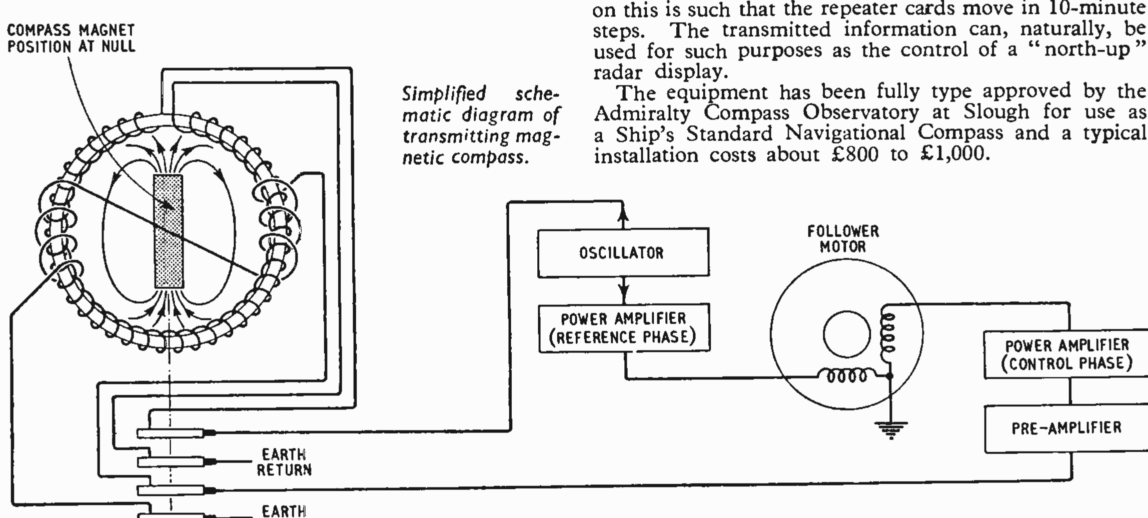
Transmitting Magnetic Compass

BY comparison with the gyro compass the magnetic compass has hitherto suffered from the disadvantage that it does not lend itself readily to the addition of repeaters.

In the Kelvin-Hughes Transmitting Magnetic Compass a standard magnetic compass is used and all necessary attachments are external to the compass bowl. Below the bowl is mounted a rotatable detector unit, which is essentially a toroidal transformer wound on a Mu-metal ring with the primary covering completely the ring. The two halves of the secondary winding are comparatively short and are placed diametrically opposite each other. The primary is energized with a critical saturation current from a 200c/s oscillator (of the thermistor-stabilized Wien bridge type). As the Mu-metal ring is saturated any output from the secondary coils would be at 400c/s; but no output appears as long as the field about the Mu-metal ring is symmetrical with reference to the secondaries because these are series-connected in opposition. This is the case when the compass magnet lies "in line" with the major axis (circumferential) of the secondary coils; but as soon as the field is disturbed so as to become asymmetrical about the secondary coils the balance between their individual outputs is disturbed and cancellation no longer occurs. With the value of primary current and winding characteristics used this output is of the order of 5 to 10mV per degree of deflection of the compass magnet from the null point: it rises to a maximum at 90° deflection, the phase (advanced or retarded) depending on the "sense" of deflection. The 400c/s signal from the secondary coil is passed to a power amplifier which feeds one winding of a two-phase motor whose rotation is geared to the detector coil assembly. The other phase of the motor is fed continuously with 400c/s derived, by a bi-phase rectifier and wave-shaping circuit, from the 200c/s oscillator. Thus the motor is caused to turn as soon as the compass magnet swings away from the null position, the direction of rotation depending on the relative phase of the two 400c/s signals and tending to bring the detector coil to the new null position. Although the amplitude of the secondary-coils output falls to zero for the 180° out of phase condition of the follower mechanism and compass card, in practice the system cannot lock in this position as the phase of any error signal from the secondary windings tends to drive the follower motor away from this null position. In any case, it is virtually impossible to reach accidentally this state of affairs as the ship cannot turn faster than the servo system.

The motion of the detector coil is coupled to a step-by-step transmitter, whose output is used to operate the repeaters placed throughout the ship; the gear ratio on this is such that the repeater cards move in 10-minute steps. The transmitted information can, naturally, be used for such purposes as the control of a "north-up" radar display.

The equipment has been fully type approved by the Admiralty Compass Observatory at Slough for use as a Ship's Standard Navigational Compass and a typical installation costs about £800 to £1,000.



Simplified schematic diagram of transmitting magnetic compass.

The Bifilar-T Circuit

An Important Filter Investigated from First Principles

By *THOMAS RODDAM*

ON and off during the last two years I have thought that I should write something about the circuit which television receiver designers call the bifilar-T trap. This circuit made its appearance in 1956 in an American colour television set and was immediately analysed in editorials in the April and May, 1956, issues of *Wireless Engineer*. You might say that it is not for the likes of me to go shoving in on the tail of better men, but the analysis there was confined to the specific needs of television and did not really worry about the general problem of design. A more recent article in the same journal (now entitled *Electronic and Radio Engineer*) for July, 1958, follows much the same lines, and at one point the authors announce cheerfully that the ratio of two inductances may be anything between 2 and 6 or, they add, presumably higher. Surely, I thought, it should be possible to find a best value.

When I came to take a fresh look at the bifilar-T I realized that if nobody was breathing down my neck and telling me how new and clever it was it became immediately recognizable as an old friend. This had, indeed, already been pointed out in the correspondence columns of *Wireless Engineer* (July, 1956, issue), but I, like everyone else dealing with the circuit, overlooked this reference: not everyone else, perhaps, because someone has borrowed my copy of this issue and has not returned it. However, the circuit is important enough to merit a complete survey, and this one, prepared away from all the references, has at least the merit of being based on almost first principles.

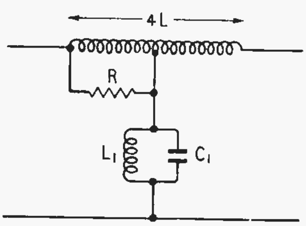


Fig. 1 Essentials of the bifilar-T circuit.

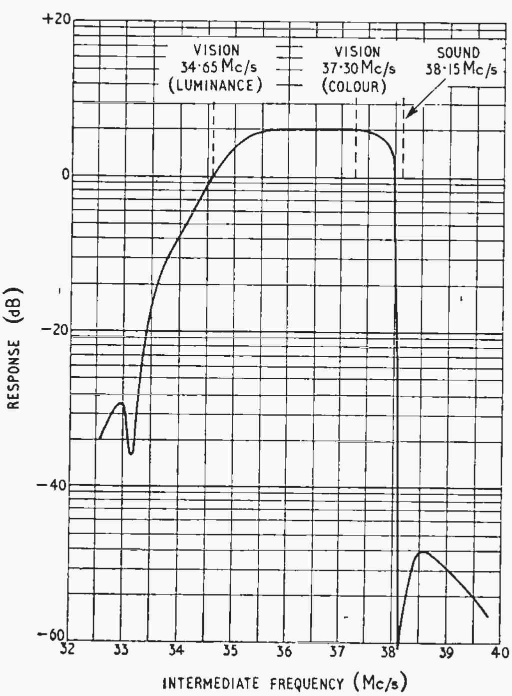


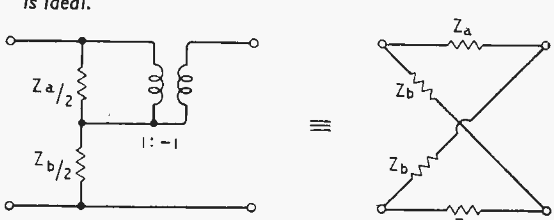
Fig. 2 Overall response curve of a colour television receiver incorporating the bifilar-T circuit as a sound-channel rejector.

The standard way of drawing the bifilar-T circuit is shown in Fig. 1. The centre-tapped coil is wound as a bifilar structure so that the coupling between the two halves is the maximum possible. The sort of performance which this circuit gives is shown in Fig. 2 and the characteristic feature claimed for the circuit is the extremely sharp rejection at the sound carrier. I do not believe that the circuit really does give a gain of 6dB, which was my first reaction to Fig. 2; it seems that the 34.65-Mc/s level has been taken as an arbitrary zero. Nor does the circuit provide all the rejection at other frequencies, for Fig. 2 is an overall receiver characteristic. Still, it is a good sharp notch, and they say that it's the bifilar-T that is responsible.

Given Fig. 1 and a reasonable amount of application, a series of $T-\pi$ and $\pi-T$ transformations brings you to a rather frightening-looking π-section having as its top arm the parallel combination of a negative inductance, a negative capacitance and a negative resistance with a positive inductance and a positive resistance. Equating the resistances and fiddling about, we finish up with an anti-resonant circuit with negative L and C. This, we must assume, will give an infinite impedance at the stop frequency: it also brings the average designer to a full stop.

Suppose that we start again and that we begin by reaching for Volume II of Guillemin, Communica-

Fig. 3 One of the classical equivalences. The transformer is ideal.



tion Networks. I cannot give a page reference because as I write I am admiring the way the rain conceals the cloud hovering over the snow on a neighbouring Alp. Some, but not all, of the hay is in. However, even though I have no reference books handy, I can give you a rather interesting circuit equivalence, and it is shown as Fig. 3. This, in fact, is a circuit which Caver found very attractive and it made a frequent appearance in his work.

This is almost the whole story. At least, so I thought until I started to sketch out the figures which form the development of the story. Let us see what happens when we try to convert Fig. 1 into a circuit we know all about. The first step is to make use of the equivalent in Fig. 3 and this you will find in Fig. 4. The loss in the coil L_1 has now been introduced as a parallel resistance R_1. If there were no loss in L_1 we should not need R: indeed there is no end to what we could do if we had a perfect coil. The assumption that all the losses can be lumped together as a single constant parallel resistance is one which we always make in these resistance compensation circuits. So long as we are only interested in the notch itself it is, of course, valid, but the reader who is concerned to see where it breaks down should refer to a paper by W. P. Mason in the October, 1937, issue of the *Bell System Technical Journal*, in which Mason criticizes severely the assumption by V. D. Landon that the advantages of resistance cancellation could be obtained over a substantial band-width.

Another Network Theorem

Now, back to our circuit. There is another network theorem, due, I think, to Norton and shown in Fig. 5. This enables us to remove a parallel element which appears in both arms of the lattice and bring it out to the end, or vice versa as we shall see in the course of our explorations. Our first use of the theorem will demonstrate the most common application. When we look at the lattice of Fig. 4 and think about taking out the loss resistance terms we see that if we make $2R = 2R_1$ the network which remains will be purely reactive. It would have led to the same result to have taken out, say, 2R, leaving $2R_1$ and $-2R$ in parallel in the diagonals and then to have said let's make this infinite. Anyway, we now progress to Fig. 6. The two resistance elements at the ends will be absorbed into the source and load resistances and we have a neat little reactance lattice which is pretty obviously a single filter network. Just what sort of a filter it will be I cannot for the moment remember, because one does not use lattice networks in everyday design. Fortunately, with the lattice network it is very easy to discover just what its characteristics are without doing any mathematics: someone has done the mathematics, of course, and you can always go off and read the theory in detail. What we need here, though, are some simple rules.

Consider the lattice in Fig. 3. You can unfold the network about a fold line passing through either the left-hand or the right-hand pair of terminals and you will recognize immediately a simple bridge. This bridge is balanced if $Z_a = Z_b$, so that in filter language this is the condition for infinite attenuation. If Z_a is nearly equal to Z_b the bridge is nearly balanced, the filter is giving some attenuation. Since we are thinking in terms of classical filters the

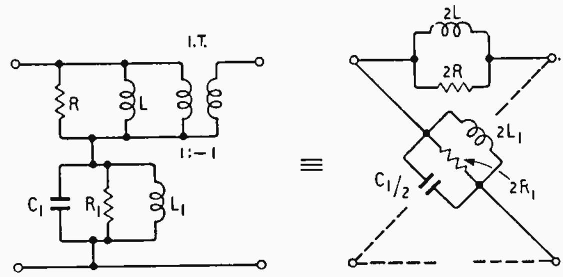


Fig. 4 Applying the equivalence of Fig. 3 to the circuit of Fig. 1. The dotted arms are the same as the corresponding arms shown in detail.

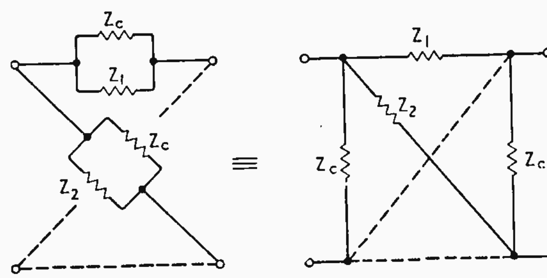


Fig. 5 One of a pair of network equivalences which are useful in dealing with loss and capacitance elements.

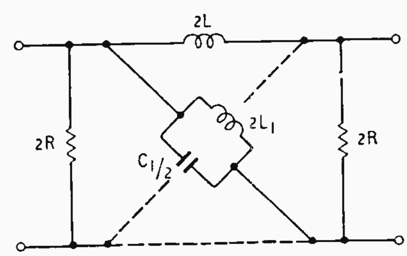


Fig. 6 Applying the equivalence of Fig. 5 to the lattice in Fig. 4.

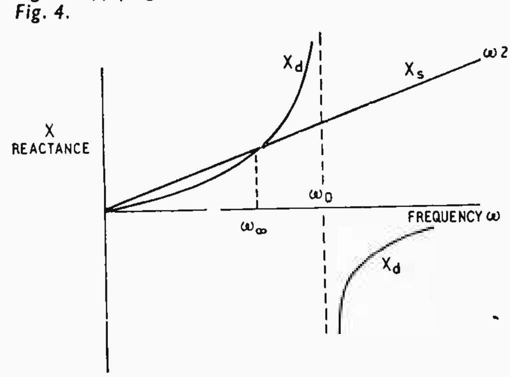


Fig. 7 The reactance characteristics of the series (X_s) and diagonal (X_d) arms of the lattice in Fig. 6.

Z's are pure reactances, of course. For mnemonic purposes it is sufficient to remember that a filter has two kinds of behaviour, passing and stopping, and that in a lattice the distinction is made by whether the resistance signs are the same or different at the frequency in question. That is why I was not

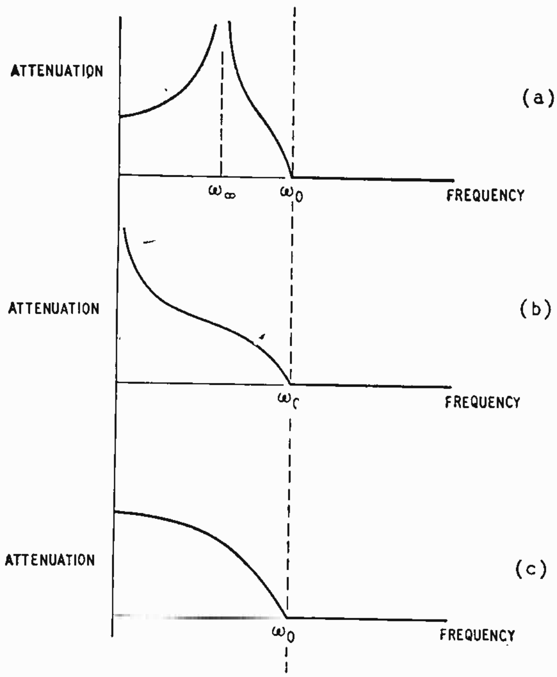


Fig. 8 Attenuation characteristics derived from Fig. 7.

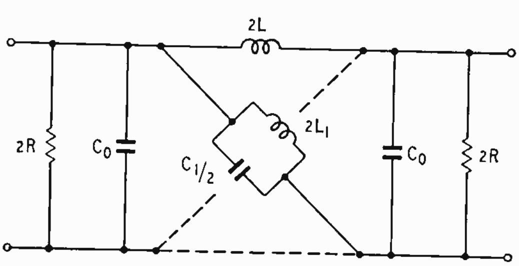


Fig. 9 The end capacitances have been added to the equivalent circuit of Fig. 6.

perturbed to find that I could not remember what sort of a filter we have in Fig. 6. We can soon find out.

The two reactance characteristics are sketched out in Fig. 7. The series arm, with its impedance of $j\omega.2L$, is a straight line of slope 2L. The diagonal arm shows the usual $x/(1-x^2)$ form, with its infinite point, at which it moves across from $+\infty$ to $-\infty$, at ω_0. At zero frequency it is obvious that $C_1/2$ cannot have any effect, so the slope of the reactance characteristic here must be simply $2L_1$. As you can see, I have drawn the characteristics for the condition $L > L_1$, and as a result the two curves cross at the point ω_∞. If L_1 is increased or L decreased, and in the first case C_1 modified to keep ω_0 constant, the point of intersection will slide to the left until, with $L_1 = L$, the two curves are touching at the origin only and then, with $L < L_1$, they never really meet at all.

I must digress here to point out that here there is a need to distinguish between zero frequency and d.c. In circuit analysis it is best to regard d.c. as something associated with the external energy supply and having as its main feature the fact that it is neutral, colourless, like a Chestertonian waiter or postman. Zero frequency, on the other hand, involves a pent-up dynamism which is more clearly understood if you consider the period as the basic concept. For many problems one cycle per second is as good as z.f., for most, one cycle per day. A bold man might quibble about one cycle per year and we can bid him up towards infinity without ever needing to reach it. I am dealing with this point here because it is important to ω and because misunderstanding appears to be widespread.

Going back to Fig. 7, we must try to sketch out the attenuation characteristics of the filter. Above ω_0 the reactances X_d and X_s are of opposite sign, so that the attenuation is zero: below ω_0 the reactances have the same sign, so that there is attenuation. The boundary between these two regions, ω_0, is the cut-off frequency. Furthermore, at ω_∞ the two reactances are equal, so that the attenuation is infinite, and at zero frequency the reactances are in the ratio L/L_1 so that the attenuation is finite. Drawing it out we arrive at Fig. 8(a). As we make L and L_1 more nearly equal we move ω_∞ to the left until when $L = L_1$ we have the condition shown in Fig. 8(b). If L_1 is greater than L we get Fig. 8(c).

You will see why I found my first sketches of these characteristics disconcerting. Fig. 8(a) is quite certainly a high-pass filter with a single frequency of infinite attenuation: Fig. 2 calls for a low-pass filter. Someone seems to have been up to some monkey

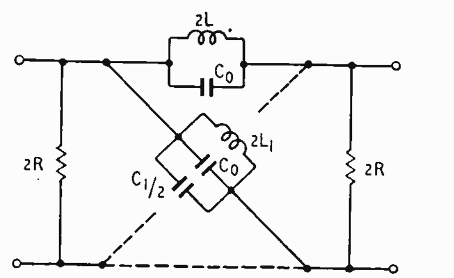


Fig. 10 Using the equivalence of Fig. 5, C_0 is brought from the ends into the lattice itself.

business somewhere. With some relief I found that Messrs. Hendry and McIntosh, in the July, 1958, issue of *Electronic and Radio Engineer*, showed for the audio frequency basic bifilar-T circuit a response which, but for a mismatch bump we can discuss later, is very like Fig. 8(a). It is the other way up, because they have measured response, but it is the same shape.

Valve Capacitances

This situation is particularly distressing because I had hoped that at this point I should be embarking on the agreeable task of discussing the design rules which would enable us to predict rather more of the response of a bifilar-T than its notch. Now even the notch has moved over to the wrong side of the pass band.

We are left with the rather unpleasant thought that perhaps someone has blundered, perhaps we have been analysing the wrong circuit. We have taken no account of leakage inductance, for example. Remembering that this circuit appeared first in the intermediate frequency section of a television receiver, my own instinct leads me to suggest that there are some valve capacitances to be considered. In the second *Wireless Engineer* editorial the valve capacitances are, of course, included in the calculation, but it is not pointed out that they play this rather important part in shape determination. This guess is confirmed by some of the results of Hendry and McIntosh, though I don't really find it easy to follow their mathematics. Anyway, let us draw Fig. 9, which is Fig. 6 with end capacitances added.

Now is the time to make use of the network equivalent of Fig. 5 in reverse. We can take the capacitance elements C_0 away from the ends and put them into the lattice, to give us the network shown in Fig. 10. At first it looks as though the variations on the reactance plots of the kind we used in Fig. 7 would be so many that one might as well give up. When we come to draw them out, however, we find that with a systematic approach the reactance diagrams are quite easy to arrange into their places. For the sake of generality let us assume that the capacitance in parallel with $2L_1$ is C_9 and that it may have any value whatever. Later we can impose the condition that it should be greater than C_0. It turns out to be easier still if we consider just two anti-resonant circuits L_AC_A and L_BC_B in which $L_A > L_B$. The reader who asks, "but what if $L_B > L_A$?" is requested to go smartly through the diagram: changing round the lettering: the shapes will not alter.

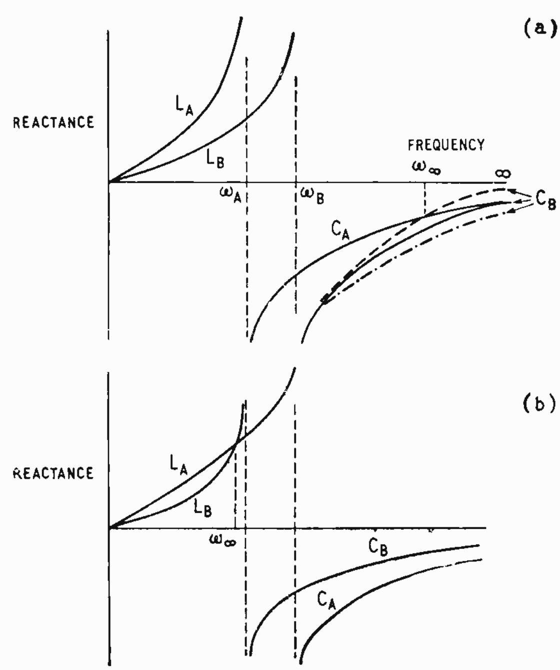


Fig. 11 Reactance diagrams for the generalized form of the lattice in Fig. 10.

The anti-resonant frequency of L_xC_x is ω_x, where x is either A or B. First let us assume that $\omega_A < \omega_B$. This enables us to draw the left-hand half of Fig. 11(a). Now since $L_A > L_B$ and $\omega_A < \omega_B$ it is perfectly possible that $C_A = C_B$. The solid curves in the right-hand half of Fig. 11(a) show this condition, with the two reactance curves meeting at $\omega = \infty$. But C_B could be a little less or a little greater than C_A without making the other two conditions inconsistent. If C_B, which is the one I have chosen to vary, is less than C_A the reactance curves do not meet, but if it is greater than C_A they cross at some frequency ω_∞. These two possibilities are dotted on Fig. 11(a).

Suppose now that $\omega_A > \omega_B$. The reactance curves must cross in the left-hand part of the diagram, as you can see in Fig. 11(b). Since $L_A > L_B$ and $\omega_A > \omega_B$ there is no choice left, C_B must be greater than C_A and we can sketch in the right-hand side of Fig. 11(b). Let us consider what happens as we increase L_B in this diagram, keeping ω_B constant. C_B will still be less than C_A, so we need not worry about the right-hand half of the diagram. The cross-over point ω_x will slide to the left until, with $L_A = L_B$, it occurs at the origin.

Attenuation Characteristics

Now we have all the information we need for drawing the attenuation characteristics. Making use of our rule that when the reactances are of opposite sign the attenuation is zero, and that when the reactances are equal it is infinite, it becomes a very easy matter to sketch out Fig. 12. Now we find we have a band-pass filter with band edges at ω_A and ω_B and with a single peak which may be above or below the band.

In our bifilar-T we have $L > L_1$, so that L is L_A and L_1 is L_B. Looking at Fig. 10, we obviously have $C_B > C_A$. These conditions can be satisfied by curves in both Fig. 11(a) and Fig. 11(b), but they do ensure a single attenuation peak, which may at choice be above or below the pass-band.

The attenuation curves of Fig. 12 remind us that we are dealing with filters of classical design and that all we really need to do is to take down from the shelf the appropriate reference book, work out the ladder network we want and then make use of Bartlett's bisection theorem to turn it into a lattice. I do not propose to do our example in this way, because I cannot for the moment reach the shelf. Let us stick to first principles for the moment.

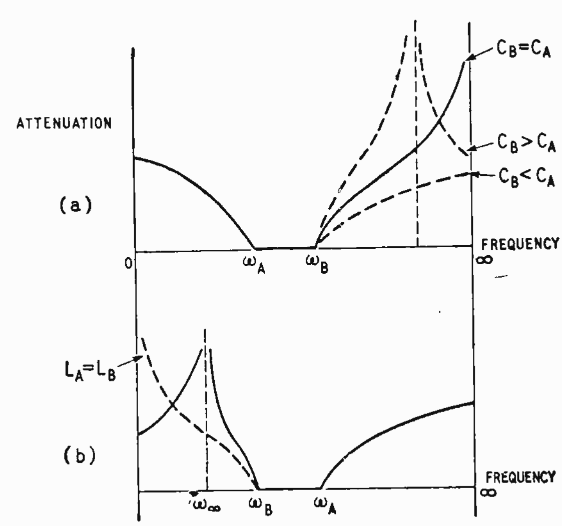


Fig. 12 Attenuation curves derived from Fig. 11.

The impedance of each arm of the lattice can be written as

$$Z_x = j\omega L_x \,/\, (1 - \omega^2 L_x C_x)$$
$$= j\omega_x L_x \,.\, (\omega/\omega_x)/[1 - (\omega/\omega_x)^2]$$

We are especially interested in the point $\omega = \omega_\infty$, when $Z_A = Z_B$, so that

$$\omega_A L_A \,.\, \frac{\omega_\infty/\omega_A}{1 - (\omega_\infty/\omega_A)^2} = \frac{\omega_B L_B \,.\, \omega_\infty/\omega_B}{1 - (\omega_\infty/\omega_B)^2}$$

so that $$\frac{L_A}{L_B} = \frac{1 - (\omega_\infty/\omega_A)^2}{1 - (\omega_\infty/\omega_B)^2}$$
$$= \frac{1 - (f_\infty/f_A)^2}{1 - (f_\infty/f_B)^2}$$

Looking at Fig. 2 in order to put in some number we might guess

$$f_A = 35\text{Mc/s}$$
$$f_B = 38\text{Mc/s}$$
$$f_\infty = 38.15\text{Mc/s}$$

so that we cannot just use a slide rule.

If x is small, $(1+x)^2 \approx 1 + 2x$. Thus

$$\frac{L_A}{L_B} = \frac{(38.15/35)^2 - 1}{(38.15/38)^2 - 1} = \frac{(1 + 3.15/35)^2 - 1}{(1 + 0.15/38)^2 - 1}$$
$$= \frac{1 + 6.3/35 - 1}{1 + 0.3/38 - 1}$$
$$= \frac{6.3}{35} \cdot \frac{38}{0.3} = 22.8$$

If we write $L_A/L_B = \kappa$ it is a few simple steps to derive the expression

$$\frac{\kappa - 1}{f_\infty^2} = \frac{\kappa}{f_B^2} - \frac{1}{f_A^2}$$

So long as κ is large, therefore, the peak at f_∞ is fixed mainly by f_B and only slightly by f_A. The form

$$\frac{1}{f_\infty^2} = \frac{\kappa}{\kappa - 1} \cdot \frac{1}{f_B^2} - \frac{1}{\kappa - 1} \cdot \frac{1}{f_A^2}$$

shows that κ is not very critical, for if we moved from $\kappa = 22$ to $\kappa = 20$ the term $\kappa/(\kappa - 1)$ would change by an amount far too small to work out on a slide-rule: it is, in fact, about ½%.

I must confess that this result has surprised me. Lattice networks have the reputation of requiring excessively high precision in their elements but obviously this is not true of this particular case. Notice, though, that if κ were much greater than unity both f_A and f_B would shift f_∞ a great deal, and small changes in κ would be very important.

The expression given above for the ratio of the two inductances, together with the two equations for the anti-resonant frequencies which determine the capacitances, leave us with only one factor to be determined when we are attempting to design a bifilar-T trap. The relationship between the elements is known: what we need to find now is the scale factor. This is what we call in classical filter language the characteristic impedance and is, if my memory is correct, equal to the square root of the product of the arm impedances. We have, then,

$$Z_0^2 = -\,\omega_A L_A \,.\, \omega_B L_B \frac{\omega/\omega_A}{1 - (\omega/\omega_A)^2} \cdot \frac{\omega/\omega_B}{1 - (\omega/\omega_B)^2}$$
$$= -\,L_A L_B \,.\, \frac{\omega_A^2\,\omega_B^2\,\omega^2}{(\omega_A^2 - \omega^2)\,(\omega_B^2 - \omega^2)}$$

This is now rearranged as

$$Z_0^2 = -\,L_A L_B \,.\, \frac{\omega_A^2\,\omega_B^2\,\omega^2}{(\omega_A + \omega)\,(\omega_A - \omega)\,(\omega_B + \omega)\,(\omega_B - \omega)}$$

At the centre of the pass-band we can write

$$\omega = \omega_A + \omega_{bw}/2$$
$$= \omega_B - \omega_{bw}/2$$

and then, provided that the bandwidth ω_{bw} is fairly small compared with ω_A and ω_B, we can easily derive:

$$Z_0^2 = L_A L_B \cdot \frac{\omega_A^2\,\omega_B^2}{\omega_{bw}^2}$$

Since we know the ω's and are going to choose Z_0, we rearrange this to give

$$L_A L_B = \frac{\omega_{bw}^2}{\omega_A^2\,\omega_B^2} \,.\, Z_0^2$$

which combined with our previous expression

$$\frac{L_A}{L_B} = \kappa$$

gives us

$$L_A = \frac{\kappa\,\omega_{bw}}{\omega_A\,\omega_B} \,.\, Z_0$$

and, of course, $L_B = L_A/\kappa$.

When we look back to Fig. 10 we see that the lattice is terminated by a "built-in" load of 2R at each end. Even with ideal source and load conditions, then, we cannot work with Z_0 more than 2R. Let us write $\omega_A\omega_B = \omega_0^2$, where ω_0 is near enough the middle of the pass-band. We have then

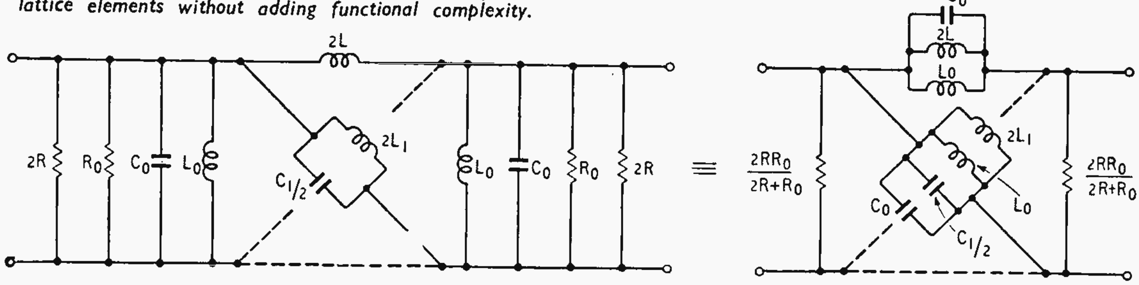
$$L_A = \frac{\kappa\,\omega_{bw}}{\omega_0^2} \,.\, Z_0 \text{ and } L_B = \frac{\omega_{bw}}{\omega_0^2} \,.\, Z_0$$

or $$\frac{\omega_0}{2\kappa\,\omega_{bw}} = \frac{R}{\omega_0 L_A} \text{ and } \frac{\omega_0}{2\,\omega_{bw}} = \frac{R}{\omega_0 L_B}$$

These two expressions define for us the Q-factors we must have in our coils to meet the basic requirement that the filter should be matched at band-centre by its own losses. In practice, of course, we never design this sort of filter to match the load impedances at band-centre because this gives us a rather rounded cut-off. It is possible that in an i.f. strip we might be happy about this, because we could use a double-humped characteristic in

(Continued on page 71)

Fig. 13 Parallel resonant end circuits merely modify the lattice elements without adding functional complexity.



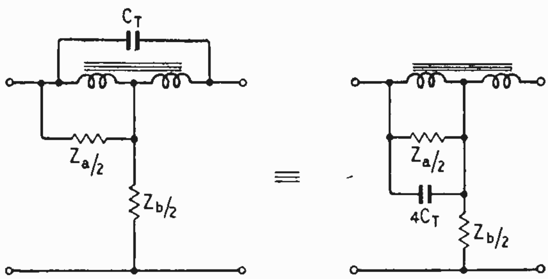


Fig. 14 A top-coupling element, such as inter-winding capacitance, is transformed to appear in parallel with $Z_a/2$ and thus appears (doubled) in parallel with the series arms of the lattice.

another interstage coupling to correct the rounding. We can make this circuit double-humped by the use of circuits of higher Q-factor than indicated by the expression above.

In the use of the bifilar-T circuit to couple together two parallel resonant circuits, everything sounds even more complicated until you look back at Fig. 5 again. Clearly it is just a matter of repeating the step from Fig. 9 to Fig. 10, but now we bring those inductances in too, putting L_0, the new inductance, across each bridge arm too. This operation is carried out in Fig. 13, without the final reduction of the parallel inductances to a single value. In the analysis above the terms L_A and L_B are now

$$L_A = 2LL_0/(2L + L_0)$$
$$L_B = 2L_1L_0/(2L_1 + L_0)$$

You will see that when we need to have $L_A/L_B \simeq 20$ it will be necessary that L_0 should be very much greater than 2L. No doubt we must have these inductances at the ends in order to get the supplies to the valves, but they do not really add to the functional complexity of the circuit. We are therefore not getting our money's worth in extra performance because we are only using two coils in parallel to do the work of one.

One problem which may arise in the construction of a bifilar-T trap is the capacitance between the windings of the transformer. This capacitance actually appears in the lattice in quite a convenient way which can be found from another lattice equivalent given by Guillemin. I prefer, however, to draw the circuit of Fig. 3 with added capacitance in the way shown in Fig. 14, which shows very simply how C_T across the top becomes $4C_T$ across $Z_a/2$, and then, in its turn although I have not bothered to draw it, becomes $2C_T$ across each Z_a in the lattice. We could make the structure more complicated-looking by adding an inductance in parallel, too, but Fig. 14 makes it clear that it would be a complete waste.

(*To be concluded*)

Commercial Literature

Sintered Components.—An illustrated booklet outlining the general techniques of powder metallurgy and giving advice to engineers on the design of parts to suit the process. From Basildon Metal Powder Parts, Church Road, Thundersley, Essex.

V.H.F. and U.H.F. Measuring Instruments and components imported mostly from American and German firms. The first of a regular series of bulletins from Aveley Electric, Ayron Road, Aveley Industrial Estate, South Ockendon, Essex.

Industrial Television Equipment for 625/405/525 line standards using plug-in units and printed circuits. An abridged technical specification on a leaflet mainly intended for business executives, from E.M.I. Electronics, Hayes, Middlesex.

Ribbon Microphone, type 4038, with figure-of-eight polar response and substantially flat frequency response from 30c/s to 15kc/s. This and three other well-established microphones (moving-coil) described with technical specifications in leaflets from Standard Telephones and Cables, Connaught House, Aldwych, London, W.C.2.

Transistor Pre-amplifier Mixer for control and fading facilities, intended for use with tape recorders. Standard models (three or five transistors) are for two low-impedence microphone inputs and one high-impedance input. Power supply from a 4-volt mercury cell. Leaflet from Penco Products, 36 Coniston Road, Kings Langley, Herts.

pH Meters, thermo-couple and d.c. potentiometers, Wheatstone bridges and other laboratory instruments. Brief descriptions in a new illustrated folder with a price list from the Doran Instrument Company, Stroud, Glos.

Loudspeakers, a range of twelve quality models including bass and treble types, with cast aluminium frames. An illustrated leaflet with brief descriptions and tabulated data from Bakers " Selhurst " Radio, 24 Dingwall Road, Croydon, Surrey.

Pulse Height Analyser for analysis of complex pulse amplitude spectra into groups of known amplitudes. Maximum mean counting rate is 1,600 p.p.s. and the storage capacity is 2,400 binary digits. Either digital or analogue display of the store contents is possible on the c.r.t. Leaflet from Marshalls' Flying School, The Aerodrome, Cambridge.

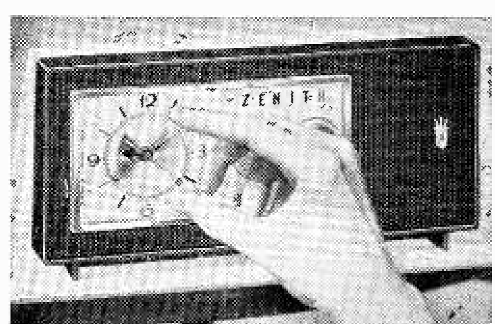
Stereo Control Unit for reproduction from tape, disks and radio, with push-button input selector. Valves: two EF86s and three ECC83s. Also a switched f.m. receiving unit and advance information on a new three-speaker **Column Loudspeaker System** and a table cabinet for housing various combinations of equipments. Leaflets from Rogers Developments (Electronics), 4-14 Barmeston Road, Catford, London, S.E.6.

BATTERY CLOCK RADIO

A TRANSISTOR radio receiver incorporating a battery-driven clock has recently been introduced by the Zenith Radio Corporation (U.S.A.). A separate 1½-V cell drives the clock for about a year and four mercury cells give about 400 hours operation of the receiver, which covers the medium-wave band.

By means of a bezel ring surrounding the clock face, the receiver may be set to switch on at any given time to serve as an "alarm." The price in America is $85.

Zenith "Royal 850" battery clock-radio receiver.



Ionosphere Review 1958

SUNSPOT MAXIMUM

By *T. W. BENNINGTON**

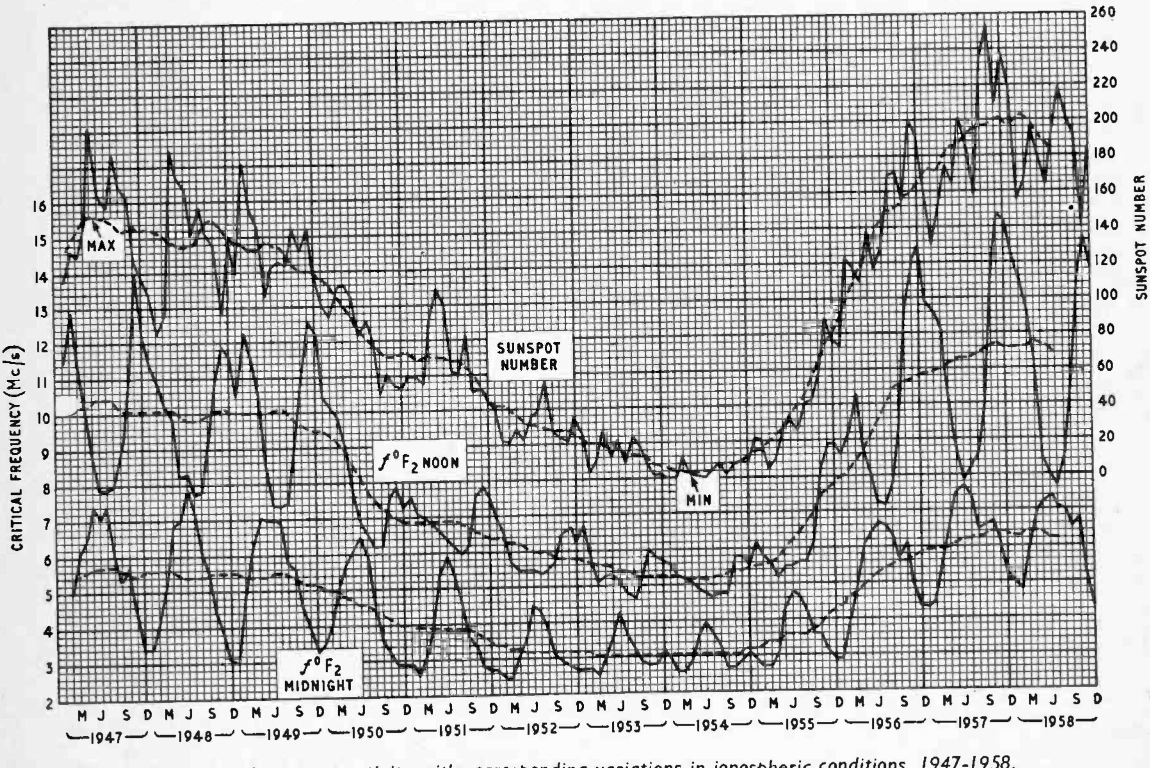
As readers may have gathered from the lay Press, the International Geophysical Year has coincided with a period of remarkably high solar activity. During 1957 and 1958, the last 18 months of which constituted this period of intense scientific effort, the average activity has remained at a higher level than that recorded at any time during the previous 19 sunspot cycles, covering a period of about two centuries. This is a fortunate circumstance for the scientists, and one of which we, who are interested in the upper atmosphere mainly as a communication medium, may also take some note, for it means that during 1957 and 1958 it has been possible to observe radio propagation phenomena under conditions which occur relatively infrequently, at least when measured by ordinarily used time standards. However, the activity during 1958 was, in fact, somewhat lower than during the previous year.

Course of the Sunspot Cycle.—An appraisal of the situation can be made from a glance at the graphs. In this the upper graph is a plot of the sunspot numbers (indicative of the degree of solar activity) and the two lower graphs are of the noon and midnight F_2-layer critical frequencies as measured at the D.S.I.R. station at Slough (indicative of the level of F_2 ionization). In all the graphs the full lines give the monthly mean, or median, values whilst the dashed lines show the twelve-month running average of these, and so indicate the average conditions. The general correspondence in the shapes of the three dashed-line curves indicates the response of the F_2 layer to the changing activity of its producing agent, the sun.

From the sunspot minimum epoch in April/May 1954 solar activity rapidly increased to reach, towards the end of 1957, remarkably high values and some which have not, in fact, been equalled during 1958. The peak monthly value, it will be seen, occurred in October 1957, and it is of interest to compare this with the values reached at the last sunspot maximum, which was itself a very high one. Early in 1958 there was some decrease in the activity but throughout the year it has, despite fluctuations, remained very high. The twelve-month running-average value reached a peak at the epoch February/March 1958. And, since it has not subsequently shown signs of increasing to a yet higher value we might assume that that was the epoch of sunspot maximum. But we cannot, as yet, be positively certain about this.

The noon critical frequency, it is seen, has shown but slight signs of a decrease during the year, the

*Research Department, British Broadcasting Corporation.



Variations in sunspot activity with corresponding variations in ionospheric conditions, 1947-1958.

summer values being of the same order as those for last year, and the winter values just failing to reach the very high values reached last winter. In the case of the midnight values they were slightly lower during the summer and of the same order this winter, compared with the corresponding values for last year. Altogether, therefore, as is shown by the flatness of the running-average curves, there has been very little change in F_2-layer ionization due to the sunspot cycle during 1958, and the ionospheric measurements indicate that very high frequencies should have continued to be usable for communication.

Usable Frequencies.—This has been borne out in practice, the usable frequencies for long-distance communication having remained remarkably high, indeed, frequencies far higher than the highest normally used for this purpose have been commonly received at long distances. The highest broadcasting frequency band—26Mc/s—has, for example, remained usable throughout the year, and the 28-Mc/s amateur band has been so for the greater part of it. Over the North Atlantic circuits the highest frequencies receivable have followed a similar pattern to that for last year, decreasing from values of the order of 58Mc/s in January to about 29Mc/s during the summer months, and rising again to about 56Mc/s in October and 50Mc/s in November. The highest frequency receivable for 50% of the days during any month was, of course, considerably lower than this, but was well over 40Mc/s during the winter and of the order of 26Mc/s during midsummer months. The Crystal Palace sound (41.5Mc/s) and vision (45.0Mc/s) channels continued to be received in South Africa, reception reaching a peak in March, when, between 1000 and 1800 G.M.T. reception of the sound channel was obained for well over 50% of the total time, and of the vision channel for about 30% of the time. During May to August this reception became relatively infrequent, but during September to November it again increased, though to somewhat lower percentage values than in the spring.

All these facts provide practical evidence of the unusually high degree of ionisation of the F_2 layer under present conditions, and of the very high frequencies which it is capable of propagating over long distances.

Ionospheric and Magnetic Disturbances.—It is interesting to observe, at this phase of the sunspot cycle, how the incidence of ionospheric and magnetic disturbances has varied since sunspot maximum in 1945. The table gives some figures obtained from magnetic and ionospheric measurement data, according to disturbance criteria used by the author, and from reports of sudden ionospheric disturbances.

All the phenomena listed, it will be noticed, increased from low values in the sunspot minimum year of 1954, to reach peak values in 1957, and in 1958 the incidence of the disturbances has noticeably diminished. In the case of the sudden ionospheric disturbances, since these are intimately connected with solar flares which always occur in association with sunspots, it is expected that the decrease in their incidence will continue during the next several years, as the sunspot activity declines. The magnetic and ionospheric "storms" may, however, continue to have a high rate of occurrence, or even to increase, until about a year before sunspot minimum. This is because, during the declining phase of the sunspot cycle, the solar corpuscles which apparently cause these disturbances appear to be emitted from the sun from regions where there is no sunspot activity. However, it was perhaps fortunate that during the I.G.Y. a large number of disturbances occurred, for, from the great mass of data obtained during their progress, the scientists should be able to learn a great deal more about them, and some of this knowledge may prove to be of benefit to those engaged in radio communication.

The Coming Year.—As for 1959 it seems probable that the solar activity is likely to decline but very slowly throughout its course. If that be so, we may expect the long-distance usable frequencies to remain much as they were during 1958. The highest receivable frequencies are likely to decrease somewhat, but these are well above the bands allocated for long-distance communication. By next winter, however, it is likely that the decline in solar activity may begin to make itself felt, principally in the necessity for somewhat lower frequencies for night-time communication.

TABLE

Year		1954	1955	1956	1957	1958
Days of Magnetic Disturbance		66	57	125	121	101
		18%	16%	34%	33%	28%
Days of Ionospheric Disturbance		75	102	132	140	126
		21%	28%	36%	38%	34%
No. of Sudden Ionospheric Disturbances		0	7	67	94	59

110° CR Tubes

TWO television cathode-ray tubes with the new 110° deflection angle are now available from Siemens Edison Swan, Ltd., 155, Charing Cross Road, London, W.C.2. They are the 17-inch CME1703 and the 21-inch CME2101. Both are electrostatically focused types with rectangular aluminized screens. The increased scanning angle gives a reduction in overall length, compared with Ediswan-Mazda 90° tubes, of about 2½ inches for the 17-inch type and about 5½ inches for the 21-inch type. Neck diameters are also reduced (to make the deflection coils as effective as possible in scanning the wider angle) and this necessitates the use of the small B8H base for the connections. The electron guns are straight types with no ion traps. Improved screens with silver activation (introduced also in other new Ediswan-Mazda types) are claimed to give 20% more light output for a given e.h.t. voltage than those of previous tubes. Incidentally, the firm has also brought out two new frame scanning valves for use with the 110° tubes, the 30P18 and 30PL13.

LETTERS TO THE EDITOR

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

Plymouth Effect

THE Plymouth Effect which is the subject of an article* in your December issue appears to be identical with a phenomenon observed some years ago by the writer at frequencies of the order of 15 Mc/s. In this case signals from a transmitter in the Portsmouth area were being received at a point on the coast about five miles to the east. Rapid and violent fading was at first attributed to scatter from a rough sea, the direct signal being attenuated by the overland path and by the coincidence of nulls in the radiation patterns of the aerials. With the return of calm weather, however, the effect persisted unchanged. It was also independent of the state of the tide or the time of day.

The direction of arrival of the signals was rather diffuse and consistent with an indirect path via reflections from the Isle of Wight which appeared to have an equivalent reflecting area of the order of 10,000 square metres. The signal envelope was not analysed in detail but appeared to have a Rayleigh-type amplitude probability distribution, varying between several times the mean level and a small fraction of it. Modification of the aerial systems to favour the direct overland path reduced the fluctuations to something of the order of 20% of the mean amplitude.

The effect was also observed at about 7.5 Mc/s, using a loop receiving aerial. Orientation of the loop to reject the direct signal produced a large increase in the fluctuations but a comparatively small drop in mean signal level.

The mechanism of the fluctuations remains obscure, but is assumed to have involved several signal paths subject to random phase variations. Phase-changes are known to take place at land-sea boundaries; and the random variations of these boundaries together with the fact that four of them have to be crossed by the indirect signals is suggested as a possible explanation for the fluctuations in signal amplitude. This would apply equally to reflections from the Isle of Wight and from the Channel Islands, and could account for failure to obtain correlation with sea state.

L. A. MOXON,
Admiralty Signal & Radar Establishment.
Portsmouth.

* "More on the Plymouth Effect," by James P. Grant, Assoc. Brit. I.R.E.

Mr. Grant asks us to say that since the article published last December was written the case at Egg Buckland reported in the paragraph after the heading The "Effect" Inland' (p. 589) has since been further investigated and it has been established that the Plymouth Effect is not the cause.—ED.

AS the author of the paper referred to by Mr. Grant in his article in the Dec. 1958 issue, may I be allowed space for a few remarks?

The general mechanism of line-tearing which Mr. Grant finds so inexplicable may be deduced easily from a simple knowledge of how a television receiver works by anyone who has read my paper. There is a time lag, which may have any value, between a line of direct signal and the same line of back-scattered signal, with the result that the interference may be a positive or a negative echo Let us assume that the receiver time base is adjusted, in the first instance, to lock at its leading edge with the direct transmission of the line synchronizing pulse. Depending on the modulation voltage at the end of the previous line of back-scattered signal and on its arrival phase, the line synchronizing pulse is reinforced or swamped. If it is reinforced, the time base remains locked, but if it is swamped, and somewhere along the line the combined envelope of the signal and interference drops sharply to a low value, the time base is held by this trough in the modulation.

The effect on the picture is clearly a function of the modulation content, the delay to which the interference has been subjected and the characteristics of the time base circuit. The number of lines displaced is determined by the period for which each cycle of the necessary conditions prevails.

The example of 18th November 1957 has been selected by Mr. Grant from observations made over a long period of time to illustrate his contention that actual meteorological conditions prevailing at the time of the interference do not correlate with those suggested in my paper. It is, in fact, an example where very good correlation is present. The wavefront generated by a wind from the 180° direction lies on an east-west line and travels northward across the Channel. When it reaches Rame Head it is stopped by the land to the west, but to the east of this point it is turned in an anticlockwise direction into the Sound. It thus takes up exactly the orientation which the paper states is necessary.

If I read Mr. Grant correctly in the paragraph headed "Coastal Limits" he suggests that the land promontories to the east of Plymouth are illuminated by a reflection from the Guernsey aerials with an intensity comparable with that of the direct transmission from North Hessary Tor. What he is propounding as a serious possibility is that the attenuation over a path of nearly 100 miles from North Hessary Tor to Guernsey, and the return path of over 90 miles from Guernsey to Plymouth coupled with the fact that the power absorbed and re-radiated by the Guernsey aerials is limited by their apertures, is the same as the attenuation over a direct path 15 miles in length!

It does appear that, just as an astrologer sees portents of ill in the position of a star, so the location of the Guernsey aerials fills Mr. Grant with foreboding. I should like to assure him that there is nothing sinister in the fact that their beam points towards Plymouth or that a line drawn from them through Crystal Palace passes within 15 miles of Harwich. The sea in front of this town, though beyond the radio horizon of the Crystal Palace radiating system, does in fact receive energy from its transmissions in the same way as do the receiving aerials in Harwich town. The estimates made here of the coefficient of back-scatter gave the value 8%. The estimate for Plymouth is 7%. The evidence at present available is derived from observations made in a number of places, some as remote as the Isle of Man and Orkney. It indicates that sea-scatter interference is present to a greater or lesser extent along any coast where a television signal is receivable (be it in China or Peru), and that the amplitude of the interfering signal is about 7 or 8% of that incident on the sea.

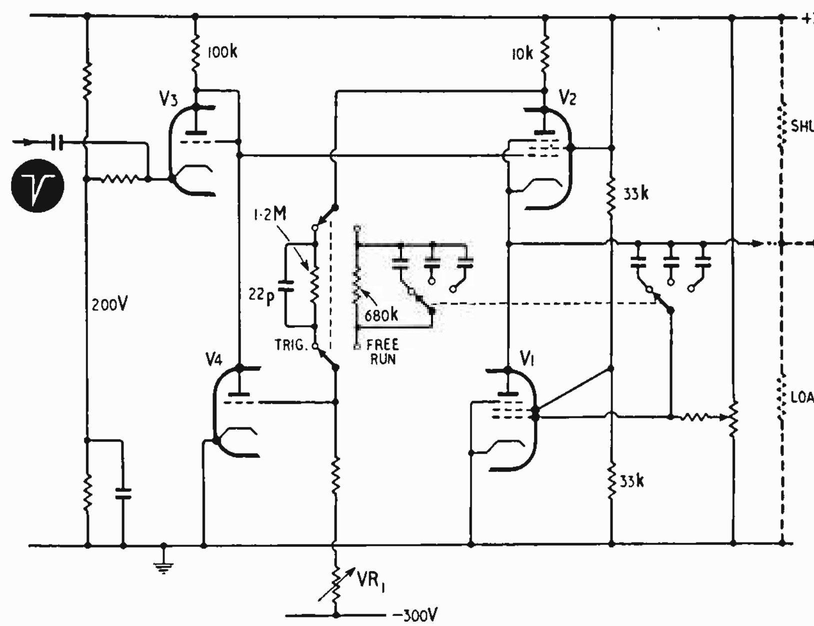
E. SOFAER,
Tadworth, Surrey. B.B.C. Research Department.

Miller Sweep Circuit

I SHOULD like to point out that the circuit arrangement, described by Mr. C. S. Speight, in the January issue (p. 34), has been used in oscilloscopes now for some years. The original arrangement, developed by Mr. L. Freeman and myself several years back, is shown in the accompanying circuit diagram.

To my knowledge, this basic arrangement, in one form or another, has appeared in at least five different oscilloscopes on the home market, manufactured by some three separate companies, one particular make of which has been available now for three years. Transistor versions have also been used in the laboratory.

In the circuit I have shown two ECF82 valves, in order to standardize the valve types. This, of course, does not alter the circuit basically. As, however, V3 cathode is at some 200V to earth, and V2 cathode rises to the same potential during flyback it is advantageous to have a double valve for these two positions and to use a separate heater winding for same.



The potentiometer VR_1 can be used (with the switch in free-run position) to stabilize the repetition rate of the timebase and if retarded sufficiently (resistance decreased) the timebase becomes essentially a triggered device. Alternatively, the switch as shown could be used to distinctly switch from free-run to triggered operation and VR_1 used as a pre-set, for optimum trigger sensitivity.

Referring back to Mr. Speight's Fig. 2, the main difference would appear to be the addition of two diodes, D1 and D2. D1, it will be appreciated, is not essential to the operation of the circuit and in the interests of economy, can well be left out, together with R_8, as the duration of flyback, and hence grid current in V1, is extremely short and well within the capabilities of ordinary valves.

Furthermore, I would suggest D2 is also unnecessary as its function can be performed more efficiently by V3, if negative sync. or trig. pulses were applied to its cathode. This would relieve V2 anode of any capacitive loading which is advantageous if this point is required for c.r.t. grid "bright-up," it also gives a faster initiation of run-down.

The use of V3 for trigger injection also ensures automatic gate-out of any pulses arriving during the actual run-down, which therefore cannot alter or affect the linearity of the display. V3 during this period is cut-off.

I should further like to mention the following points:—

1. This circuit arrangement does not eliminate the Miller step, other methods are required for this, see B. H. Briggs—"The Miller Integrator," *Electronic Engineering*, Aug., 1948, and Prov. Patent Spec. 30735/58. With this arrangement, the initial Miller step is less than in more conventional Miller circuits. However, it deteriorates slightly at the higher speeds of run-down: a further effect, due to V2 grid-cathode capacitance feeding through the switching pulse, makes matters worse. Up to sweep speeds of 30V/μsec, however, this latter effect is negligible. As the initial step is essentially constant in amplitude, in common with most Miller arrangements, it is advantageous to have as much amplitude as possible of total run-down, thus keeping the percentage of step to run-down a minimum.

2. The figures of non-linearity quoted by Mr. Speight do not take into consideration the non-linearity due to the initial step at all, or its effect on the presentation displayed on c.r.t.

3. The output can be shunted if required, by a reasonable impedance, provided a similar or slightly lower impedance is shunted across V2, with no apparent loss of linearity.

4. The following advantages seem to have been overlooked:—

(a) Constant amplitude of run-down unaffected by sync. at all speeds.

(b) Superior triggering or synchronizing ability.

(c) Voltage level from which run-down commences is constant and therefore the spot always starts at the same point on the c.r.t. display.

St. Albans, Herts. J. D. JULIAN.

Rigidity of Loudspeaker Diaphragms

IT is interesting to learn from Mr. H. A. Hartley's letter in the January issue that he manufactures what is undoubtedly a sandwich construction diaphragm speaker. I had not seen this advertised until recently, when it occurred to me that it might be of sandwich construction, but this was offset by the diaphragm being described as "wafer-thin"; this suggests that while this cone is doubtless much stiffer than the usual type, still greater stiffness could be obtained for the weight.

I am surprised that Mr. Hartley should have trouble with damp, as the pores of the expanded polystyrene which I suggested for diaphragms are not connected and the solid material itself has good water resistance. The makers claim that six weeks' total immersion in water gives only 2.8 per cent by volume absorption (which will dry out in a normal atmosphere), which is surely much better than cone paper, and simple *ad hoc* tests support this. There are a number of plastics which are not too resistant to water and many foams have interconnected or partly interconnected pores; the description of the bonding process suggests that the pores of Mr. Hartley's cone may be interconnected.

The statement that stiff cones do not seem to conform to conventional theory of speaker design and give a wide response is most interesting, as this is my own experience. Since writing the article, I have constructed a number of sandwich speakers. Thus a 7½-in diameter flat diaphragm of total moving mass 15 gm gave ample treble, no tweeter being necessary, and response extended to the limits of audibility (and doubtless beyond). A thick 7½-in diameter cone, of total moving mass 30 gm, was slightly deficient in treble but still reached the limits of audibility. In each case the treble was well distributed. While these findings are most agreeable practically, they upset theory! The diaphragms are still not infinitely rigid, but it is difficult to see how they could have an even greater treble output than conventional cones of similar diameter and weight. I agree that a stiff cone seems to show up other defects in the system, in that the above speakers show high-frequency distortion on certain types of signal for no very obvious reason.

Banbury. D. A. BARLOW.

I WAS very intrigued by a paragraph in Mr. D. A. Barlow's article in the December, 1958 issue dealing with twin cones which states: "In an alternative design, the small cone is joined at its outer edge to the inner edge of a large one by means of a compliance, forming a composite cone." I would like to point out that I was granted a patent covering just that form of composite cone (B.P. 329, 376; Application Date Feb. 18, 1929, No. 5387/29; Complete left Nov. 15, 1929; Complete accepted May 19, 1930).

Although the so-called "theory" expounded in my application may sound a little "forced" at this later date (but what application doesn't?), I still consider the principle holds, that a diaphragm needs power to begin to move it *and time*, owing to its inertia. A (much) later analysis of the whole system where a component is suspended from another also suspended component resulted in indications that the response—especially with drive applied to the first component, i.e., the inner cone —was in a series of resonances. The stiffness, etc., of the coupling between the cones was of great importance, resulting ultimately in the very familiar concentrically corrugated cone.

Which reminds me, I do not seem to find the egg container to be very rigid when loaded with eggs or its similar unit when loaded with apples! But it would appear to be another way of making a "stiff" cone— i.e., by dimpling sheet material and facing it with "stress skins."

There also exists B.P. 258,502 (1926) where the use of a large-diameter disc of balsa wood is driven by the inner cone to give suitable reproduction, the patentee states: "We are not prepared to state exactly what properties of balsa wood are responsible for the improved operation of the loudspeaker disclosed in this application, but undoubtedly the soft nature of this type of wood and its extreme lightness are contributing factors." Possibly the effect is as your contributor describes.

Breaston, Derby. R. H. PARKINSON.

Printed Circuits

I WAS most interested to read "Diallist's" comments in the January issue on printed circuits in "electronic equipment" and more particularly the letter from Mr. A. G. Tucker on this subject, and it is to this letter that I refer.

It is unfortunately true that many radio service technicians are biased against the use of printed circuits, or should I say against the repair and servicing of receivers incorporating printed circuits, and Mr. Tucker's comments seem typical of so many of the servicemen.

In the first place, I would doubt very much whether many dealers consistently give a 24-hour repair service, even using brute force methods of cutting out doubtful components and replacing them with good ones. If therefore, the only complaint in servicing receivers incorporating printed circuits is that a dealer would have to wait at least a week for a replacement circuit, then why not stock a replacement circuit in the same way as valves and other components are stocked.

I feel, however, that this is not the reason why service engineers are not entirely happy with printed circuits and in my opinion, it really comes down to the fact that more care and a higher degree of technical skill is required to do the job efficiently, whereas in the repair of conventionally wired receivers, there is more room for the hit-and-miss method which does not require as much experience or technical knowledge. I would give as an example, the experience in our own assembly works of the resistance to the use of printed circuits when production was first changed over, approximately nine months ago, but this position has now completely changed and not only are fault finders and repairers keen to work with printed circuits, but they have furthermore demonstrated that their output is greater than when repairing conventionally wired receivers.

I am aware that the type of fault finding in an assembly factory is not necessarily the same as that experienced outside, but nevertheless I feel that similar conditions will prevail.

Mr. Tucker is quite in error if he assumes that the only advantage of the use of printed circuits is to cheapen production. It most certainly does that, but it furthermore reduces the cost of the complete receiver by enabling a smaller and simpler chassis to be used as well as a smaller cabinet, it improves reliability and also gives greater consistency in performance than can otherwise be achieved.

Regarding the position in the U.S.A., it is quite wrong to say that the better television receivers are advertised as "definitely containing no printed circuits". The position is that only one manufacturer has so far not made use of printed circuitry and his advertising reflects this position by making a virtue of an existing situation. It is surely not correct to assume that such American manufacturers as Westinghouse, G.E., R.C.A., Philco and many others do not produce the best types of television receivers, and since they do and since, furthermore, 95 per cent of American radio and television equipment is now printed, then to use Mr. Tucker's own words "that surely speaks for itself".

Manufacturers in this country too are increasing the number of receivers incorporating printed circuits and it is quite certain that printed circuits are here to stay. I suggest therefore, that service engineers learn to live with them, learn the snags or problems that may arise, then overcome them and they will shortly wonder how they ever managed to repair the old-fashioned receiver using "steam wiring".

Slough, Bucks. W. I. FLACK.
Radio and Allied Industries, Ltd.

I WOULD like to take up a sentence (December, 1958 issue) in which "Diallist" says "He tells me that his service department reports that faults in receivers using such panels are appreciably fewer in number than they were when conventional wiring was in use." Well now, I tried to break this statement down and in doing so came to these conclusions.

The printed circuitry must have some magical property which prevents capacitors, resistors, transformers and the like from breaking down; or this manufacturer must have had a spate of broken wires and poorly soldered joints in this department beforehand. Alternatively perhaps the design of receivers has improved and the liability to breakdown would not occur with conventional wiring either?

To round off let me say that the last printed circuit receiver I serviced within the last week required the dismantling of an i.f. transformer to trace a fault within it. The six connections requiring simultaneous application of an iron to get at the component proved too much for anyone with normal human faculties, and a request was made to the manufacturers for a new panel. They hadn't any, no sir, not one, for a current receiver which had been less than four weeks in the customer's house. So back has gone the whole receiver to their service department while the owner—waits!

London, E.4. M. W. DONAGHUE.

WITH reference to Mr. A. G. Tucker's letter in January issue, on printed circuits, I find myself annoyed by the suggestion that the serviceman would make a guess as to which unit(s) is at fault, then having "paid his money and taken his pick" he sends the unit off to the manufacturer, only to be told he has picked the wrong unit!

As regards the suggestion that the only advantage of printed circuits is cheapness, I cannot agree. If a sensible approach is made to removing unserviceable components and fitting new ones as in the original manner

(*Continued on page 77*)

(not as is suggested by some manufacturers, that is by cutting u/s components out and hanging new ones on the old piece of wire) no great difficulty should be experienced.

Stevenage, Herts. A. E. SMITH.

Stereo

I WOULD like to join issue with Mr. B. Wallace on several points in his letter (December 1958).

Some would agree that the best position to enjoy an orchestra was so far back that complete blending of sound occurs and the orchestra almost a point source. However, even at that distance, the audience, music lovers or otherwise, don't pay their money to listen to the *whole* sound coming from a hole in the side of a wooden panel, however beautifully it might be polished. An orchestra is not intended to perform or be listened to in completely non-reflecting surroundings. The multiple reflections within the auditorium are an integral part of the performance, and we set great store by them, as evinced by our recognition of good, bad and indifferent halls; good, bad and indifferent seats within a hall. These reflections do not reach our ears from the same direction as the direct sound, and this vital part of our enjoyment can be achieved only by some stereophonic system.

With stereo our "view" of the orchestra will no longer be through a hole in the corner of the room. The whole wall will seem removed and our room grafted on to the auditorium—at a suitable place, if the engineers have done their stuff properly. Admittedly there is a present tendency to give us a front seat, but we should grow out of that in due course. When all is correct, the whole thing *feels* real the moment the studio or concert hall background noise is faded in—before even the first note is played.

Chamber music can be reproduced almost perfectly with a single channel in a suitable room, with a very good omnidirectional speaker. Few of us have a suitable music room. Ours may be too small or too heavily furnished to do it justice. In this case we transplant the chamber music studio's better acoustics into our own front room—more accurately and realistically with stereo than with a single-channel signal.

London, N.11. RALPH L. WEST.

AS so much has recently been written decrying the advent of stereophonic records I would like to join the fray as an advocate.

During the past few years many high-fidelity enthusiasts have spent fantastic sums of money in an endeavour to achieve the maximum realism of reproduction, much of the effort having been directed towards the supersonic end of the spectrum. This has resulted in what may be called a "bat-eared cult."

In my opinion, single-channel reproduction has reached the limits, and yet one cannot completely get away from the "hole in the corner" effect of a single loudspeaker array. In this respect, Mr. A. D. Levaggi (Dec. 1958 issue) pays stereo the greatest compliment when he says that one soon becomes unaware of the medium. This is as it should be.

It may seem at first consideration that Mr. B. Wallace, in the same issue, is correct when he says that a solo instrument or voice, or a chamber ensemble, would not benefit from stereo. If a performance were recorded in the open air, free from studio resonances (and how empty and dull this would sound), I would agree with his argument, but the studio or concert hall audience, so vital to a lively performance, is always present, and a single channel is incapable of reproducing this "presence" with the realism that stereo gives.

This presence, incidentally, is the reason why so many existing records suffer from lack of clarity or "woolliness" in the lower frequency range and explains why the bass fiddles can be reproduced much more clearly on a (good) stereo record of orchestral music.

It is now the duty of the recording companies to issue records with the highest standard of performance, as even the finest stereo recordings cannot atone for mediocre performances and, in fact, seem to show them up even more.

Leigh, Lancs. NORMAN WATSON.

I HAVE followed the progress of stereophonic sound reproduction since its inception, and have heard numerous demonstrations, including the series of B.B.C. experiments. I am more than ever convinced that the appreciation of sterephony is as much a psychological matter as a technical one. For myself, stereophonic reproduction is far and away more satisfying than either single-channel or two-speaker single channel, yet I have several friends, for whose mental powers I have the most profound respect, who just cannot appreciate stereophony. They say either that they can hear no difference or that it is simply the same sound coming from two sources.

Were it possible to subject a cross-section of interested persons to physical and psychological classification, I think we might be nearer to the answer. Apart from the fact that many people manage quite happily, unaware that their two ears are by no means matched either for sensitivity or frequency response, there is also the possibility of interaction between eye and ear. I think it is generally accepted that human beings can roughly be separated into two categories; those for whom sight is the predominant sense and those with aural predominance. In short, some folk appreciate and remember things they see and read much more easily than things they hear. Some learn much more easily by attending lectures than by reading a text book. I suggest that it is possible that the "visualists" may be those who do not appreciate stereophony and the "auralists" are those who do.

For myself, I am definitely an "auralist." I find even two completely unmatched channels on stereo much more satisfying than single-channel reproduction, yet a friend of mine who is a more than ordinarily successful photographer, who can spot subtle differences between two pictures which just pass me by, cannot understand what I get from stereo!

It is an interesting exercise to listen to stereophonic reproduction in complete darkness. In a lighted room, the eye is constantly telling the brain that the sound is coming from one or more point sources, conflicting with messages from the ears which say that the sound is spread out. Remove this mental conflict by eliminating this "cross-modulation" and then listen to stereo with a new perception.

Bromley, Kent. A. O. MILNE.

THE woman who cannot afford to buy diamonds is quite satisfied with artificial stones or marcasite. There is little practical difference between them beyond the psychological glitter attached to the astronomical price of the diamonds. It is very much the same with stereo reception which is almost as old as radio itself.

Loudspeakers first came into use in the early twenties for those first music broadcasts from The Hague, Holland. It was the normal practice to use headphones with the first attempts at loudspeaker operation both for "tuning in" (quite a performance in those days!) and comparing quality from the respective mediums. One of the first things to be noted with those early efforts was that a much greater degree of realism was attained when listening with headphones and the loudspeaker simultaneously; it placed one "inside the music," so to speak. It was necessary to adjust the volume of each instrument in relation to one's distance from the loudspeaker to get the correct effect. This adjustment was positive; there was no doubt when one had hit the correct balance; it was easy to make.

If it be argued that present-day listeners do not want to be bothered with headphones, the answer is that they also are not interested in paying out large sums for something that sounds "a little different" if one sits "just so." With music enthusiasts it is quite another matter; they are prepared to go a long way for anything new likely to add to their enjoyment. To these I strongly recommend a trial of the combined headphone and loudspeaker reception—particularly if they have never previously handled headphones. It will cost little. All that is required is a pair of low resistance headphones with a few extra yards of flex to extend them a reasonable distance from the receiver, to which they are connected at the "extension speaker" sockets†. These headphones can be had secondhand very cheaply but if you want to take this trial seriously, invest in a pair of comfortable modern moving coil headphones which are of a suitable resistance for the purpose.

A separate adjustable resistance could be arranged to control headphone volume, but in practice it will be found in most cases that adjustment of the volume control on the receiver will effect the correct balance between the two to attain what is, I have no hesitation in claiming, something quite as good as the present costly attempts at so-called stereo reproduction which is only stereo in bits and pieces.

London, S.W.18. B. S. T. WALLACE.

† Readers of W.W. will need no reminder that the output winding and sockets should be isolated from direct connection with the rest of the circuit or chassis—Ed.

WHEN stereophony was first being launched commercially a couple of years ago you published several technical papers and detailed descriptions of equipment which made it abundantly clear that stereo must be expensive. In a typical example, it was shown that a difference of only 6 dB between channels was enough to swing the sound image fully to one side or the other. Thus if "image splitting" was to be avoided the two channels had to be matched very exactly indeed *at all frequencies*—a requirement which could be met straightforwardly, if at some cost, in tapeheads and amplifiers, but clearly required exceptional care in both design and manufacture if it was to be fulfilled in the mechanical systems of pickups and loudspeakers.

Now we are being offered all manner of equipment allegedly suitable for stereo and most of it is quite cheap! Further, we are being told that the advantage of stereo overrides limitations of quality in the component channels. Who is kidding whom?

May I draw attention to fundamental considerations which are being forgotten in the excitement? In the concert hall, one deliberately chooses to sit reasonably far away from the orchestra precisely in order *not* to hear the sounds of the different sections from noticeably different directions. In single-channel reproduction all the sounds are blended, but a small sound source within a room is heard as such, is *located* by the "mind's ear," is recognized to be near, and in these circumstances realism can be approximated only by reproducing at the same loudness level as the original—which is out of the question for orchestral music, although complete realism can actually be attained in the reproduction of a solo instrument or voice.

For satisfying results in the home it is necessary to find a means of pushing the sound image back through the living-room wall. The simplest expedient, which is effective to a surprising degree, is to point a conventional speaker into the corner of the room. Better, if a speaker can be used which transmits a plane instead of a convex wave-front then the apparent distance of the image becomes dependent solely upon qualities of the signal itself—notably the frequency distribution and the ratio of direct to reverberant sound selected by the transmission engineer. A pair of matched speakers gives an approximation of a plane wave-front and I submit that from purely musical considerations it is the sole advantage of stereophony and can be obtained equally by using two speakers to reproduce "monaural" sound. The analytical quality of stereo is more likely to be an irritant once the novelty has worn off. Nevertheless, stereophony is an exciting technique and seems full of possibilities for all sorts of programmes other than straight music, particularly if it comes to be used regularly in sound radio. But for musical material, any suggestion that the stereo effect can compensate for increased distortion or other limitations of quality is nonsense; nor has the question been authoritatively answered whether present recording techniques and available pickups can give as good quality from each channel of a stereo disc as is possible with single-channel lateral recording.

London, W.11. IAN LESLIE.

IT has long been understood that two-channel binaural reproduction is a near ideal system and the only system of stereophony capable of easy practical achievement. Such a system demands that a position is selected for listening at the "live" end and the aural context is transferred remotely by replacing the listener's ears by "long electronic ears." The main practical considerations are that the microphones have the same directional characteristics as the ears replaced and that the channels taken back to stimulate the ears of a remote listener are free of frequency and non-linear distortion overall: the only inherent system shortcoming is that no change of auditory perspective results when the remote listener moves his head.

The question is how far can the ideal two-channel system be compromised for practical convenience. My answer is very little, and that the loss of control brought about by departing from the ideal is likely to drag stereophony into disrepute.

Two views are usually proposed for the consideration of stereophony as it is usually offered with two speakers some distance from the listener. The first view is that the original sound field is being re-created between the two speakers and the second is that each channel is intended for each ear but is laid out as it is for practical convenience. The first view is very dangerous and smacks of free-field stereophony which, although ideal, is only approachable in the laboratory employing large numbers of channels: alternatively it makes assumptions about listening rooms which are unwarranted and implies that freedom of movement is available in the sound field.

The second view is more useful and it remains to enquire the extent to which each channel does apply to each ear. Two related uncontrolled factors are involved, listening room enhancement and aural cross-talk between channels: these together with the microphone techniques at present employed account for the uncontrolled "splashy" sounds with a coarse sense of movement with which we are all becoming familiar. The recording companies are in a quandary and use microphone techniques not very different from those used for "monaural" purposes with exaggerated differences between channels.

I submit that two-channel stereophony should come out in the open with what it really is: *viz.*, a method of bringing another dimension under proper control. It should be acknowledged that listeners must be tied down to some personal controlled listening device such as earphones or very closely spaced speakers. Recording companies should give their customers a controlled replica of the sound in the best seat in the auditorium.

Maldon, Essex. W. L. GREGORY.

Save Our Shavers

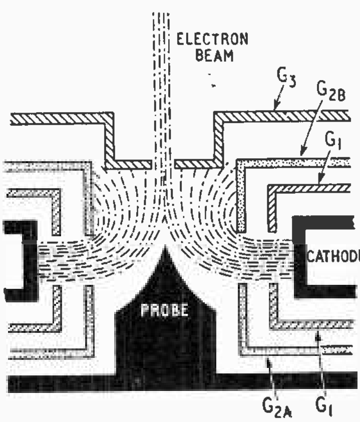
I AM pleased to note that "Free Grid" uses a low-voltage transformer to feed his electric razor, but disappointed to read of his shocking experiences with a mains voltage model in earlier days.

Other readers who are not, like myself (as a contracting installation electrician), familiar with the I.E.E. regulations, may be interested to know that the provision of outlets for portable appliances in a bathroom is strictly forbidden, except in special circumstances as defined in B.S. 3052: 1958. I do hope "Free Grid" will read this before he receives a visit from his Local Board inspector, as this might well result in immediate disconnection of the supply.

Christchurch. MICHAEL R. BOURKE.

Technical Notebook

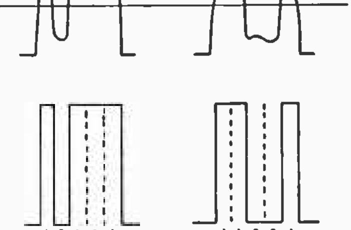
Annular Electron Gun for television c.r. tubes, devised at RCA Laboratories in America, offers the advantages of high modulation sensitivity and a small spot size which (with the focusing conditions) is largely independent of the beam intensity. In addition the gun provides internal video signal amplification and an automatic inversion of white-spot interference pulses. As shown in the sketch, the construction is based on an annular cathode, annular control grids (G_1) and accelerating grids (G_{2A} and G_{2B}), an annular grid G_3 which forms an object electrode, and a beam-bending probe. The control grid annuli are normally operated at the same potential (negative with respect to the cathode), while G_{2A} and G_{2B} are at different positive potentials (around 200V) and the



probe is at about −15V. In a conventional c.r. tube the electron-optical object is the electron-beam cross-over point, but here the object is the uniformly "illuminated" aperture in G_3, which is operated at about +50V. This 0.007in diameter hole gives a spot of nearly uniform intensity and with sharply defined edges. On the grid control characteristic of a 16-inch tube using the gun, an increase of negative control grid voltage first of all produces an *increase* of beam current and then the expected tail-off to zero, with maximum current occurring at about −15V. If the tube is modulated in a positive direction on the rising current section of the characteristic, only about 6 volts of driving signal are required for full beam modulation. Any increase of signal over full modulation ("whiter than white") produces a reduction in beam current and so provides the automatic interference inversion. Video signal amplification is obtained by inserting a load resistor in the positive supply to G_{2B}. The amplified signal obtained across this could be re-applied to G_3 or the probe to obtain a possible increase in modulation sensitivity or used for other purposes. Full details of the electron gun are given by J. W. Schwartz in the 1958 *I.R.E. National Convention Record*, Part 3.

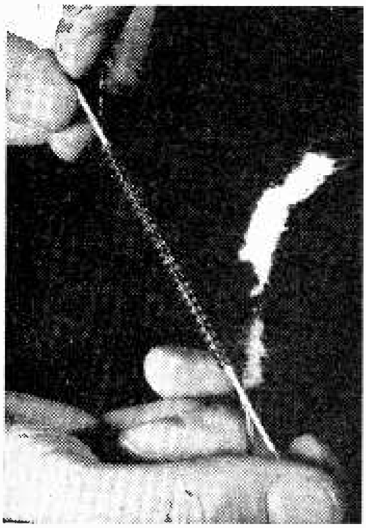
Vertical Tracking Errors in stereophonic pickups are likely with the often used cantilever, or indeed with any construction in which the stylus is connected by a rigid link of any shape to a single pivot point. Such tracking errors arise because the pivot point must lie above the surface of the record, so that the line joining the stylus and pivot point cannot be horizontal. Thus the stylus, which can move only at right angles to this line joining the stylus and pivot point, cannot move straight up and down and so cannot accurately track vertical recorded modulations, the error being about five degrees or more with practical pickup constructions. The geometrical configuration is analogous to that in the more usual type of tracking error arising with ordinary laterally-only modulated records, so that the distortion produced will depend on the error angle in the same way. Such tracking errors are equivalent to somewhat reduced errors in each of the two 45 degree modulation directions now standard for stereophonic recordings. Expressed mathematically, if θ is the vertical tracking error, this corresponds to equal tracking errors in each of the two 45 degree modulation directions of $\tan^{-1}[(1/\sqrt{2})\times\tan\theta]$ which is approximately equal to $\theta/\sqrt{2}$ for small values of θ. These errors could be avoided if the recording cutter motion was made the same as the possible stylus motion. In this connection, it is interesting to note that with the American Westrex cutter the nominally vertical cutting direction is in fact inclined at 23° to the vertical, though apparently only for reasons connected with the construction of the cutter itself (see C. C. Davis and J. G. Frayne, *Proc.I.R.E.*, Oct. 1958, p. 1689). Alternatively, true vertical motion of the stylus can be made possible by attaching it, for example, to four freely-linked rods forming a rectangle with one side vertical.

Simple Character Recognizer for business and industrial applications, devised by E.M.I. Electronics, achieves its simplicity, small size and low cost by being limited to a formalized type face designed specially for the machine. Twelve numerals from 0 to 11 and a few extra signs are used. In operation the numerals are analysed into five columns, each of which is mainly black or mainly white. For the figure 6 in the sketch, for example, the columns (reading from right to left) are black, white, white, black and black, so that if black is represented by "1" and white by "0," the numeral 6 is coded in binary form as 10011. The first digit in the code for each character is always "1" (i.e., the right-hand edge is always black), so the system gives four variable digits with 2^4 or 16 possible combinations. In the machine a narrow vertical slit scans across the numerals and the amount of black viewed through it is measured photo-electrically to give the sort of waveforms shown in the sketch. These waveforms are squared by limiters set to operate about the datum line to give the signals shown below. Identification is carried out by sampling five times, once in each column. This process is initiated by the first appearance of black in the



slit (since the first column is always black) and continued at a rate controlled by the scanning mechanism of the machine. The scanning can be varied over a wide range of speed. With this type of system it is possible to transform with little difficulty to magnetic reading. Characters printed in magnetic ink are scanned by a magnetic head whose slit corresponds to the optical scanning slit. (Such magnetic characters are of use on documents which are open to the risk of accidental or intentional defacement). The use of a single scanning slit also removes the necessity for accurate positioning of the character in the vertical direction. Accurate positioning along the line is not necessary either, for the recognition operation is triggered off by each character whenever it arrives.

Single-wire Shift Register, a computer storage system in which patterns of digits can be shifted along at will, is under development at Bell Telephone Laboratories. Based on the so-called "twistor" technique



described in our January, 1958, issue (p. 32), the register consists of a single wire of 0.002-in diameter magnetic material (Permalloy), which has mechanical torsion (the "twist") applied to it. This wire is stretched through the centre of a ceramic tube on which tiny 8-turn solenoids are wound (0.075in long and spaced 0.075in apart) for "writing" in the digit pulses and shifting them along. Owing to the twist in the magnetic wire it can be magnetized most easily in a spiral direction, and it can store pulses when subjected to a suitable magnetizing field. The amount of twist applied serves to regulate the magnetic interactions between magnetized zones. These magnetized zones can be slid along the wire under the control of pulses applied to the small solenoids. Simultaneous pulsing of three adjacent coils is necessary to insert a magnetized zone into the register. Two coils must be pulsed to slide this zone along the wire. For example, if a binary digit is stored by pulsing coils 1, 2 and 3, it can be moved along one space by pulsing coils 1 and 4. The pulse current required for the advance operation is about 140 mA. To clear the wire after a bit has been advanced, an "erase" coil is pulsed with about 240 mA. To read out the signal at the end of the register, a pulse of about 170 mA is passed through three "read-out" coils. If a binary digit is present, a voltage pulse appears across the magnetic wire. In the absence of a digit, no voltage pulse appears. Tests on a 5-advance register (see picture) have demonstrated the feasibility of this device. It is capable of storing three binary digits per inch, and calculations have shown that the capacity can be increased to ten digits per inch. Bi-directional operation can be obtained. The upper frequency limit has not been established, but a digit pulse rate of several hundred kilocycles should be possible.

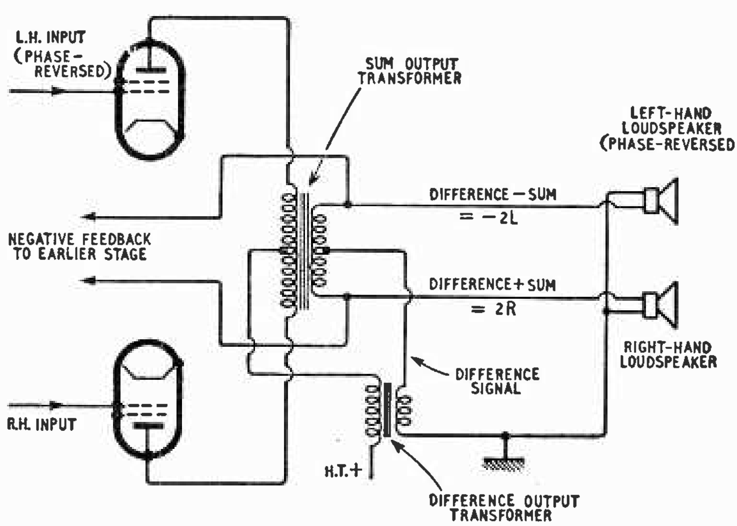
Aerial Lobe Pattern Synthesis is accomplished in a new Solartron radar simulator (developed for the Italian Army) by feeding the signals synthesizing the radar echos on to one plate of a capacitor of open construction. Between this and the other plate, from which the output is taken, an earthed metal disc is rotated in synchronism with the timebase on which the synthesized "aerial" signal is displayed. By shaping this disc appropriately (i.e., making cut-outs in it in proportion to the aerial lobes) the beam-width, magnitude and position of the aerial lobes are simulated.

Single-Amplifier Stereo.—Phantom working has long been known to line engineers: the basic principle is that a balanced two-wire circuit can carry an additional unbalanced circuit between the two lines and earth, or a pair of two-wire circuits can carry an additional balanced circuit between the two pairs. The former condition corresponds to a Class-A push-pull amplifier without a phase-splitter; that is, a push-pull signal could be fed in and extracted, amplified, in the normal way. Another signal, this time unbalanced (i.e., one side earthed), could be fed to both input stages in phase and extracted from a second output transformer in series with the h.t. feed to the centre-tap of the push-pull o.p. transformer: for this signal the amplifier operates as two "paralleled" single-ended amplifiers.

This system is used to provide "two amplifiers for the price of one" in the American Columbia Broadcasting System's range of stereophonic gramophones. Naturally, the distortion for the same power output is higher in the "paralleled" or phantom channel than in the push-pull channel and this means that it would be unwise to feed nearly identical signals to both phantom and normal inputs. If, however, the sum signal is fed into the push-pull channel and the difference signal is fed into the phantom channel the distortion produced should be acceptable because the power required for the difference signal should be less than that required for the sum. The outputs from the amplifier can be reconstituted into left and right signals by appropriate interconnection of the secondaries of the output transformers.

Another interesting feature of the system is that no input-matrixing arrangements are necessary to produce the sum-and-difference signals provided that left-hand and right-hand inputs, one phase-reversed, are available. This means that a four-terminal stereo pickup can be used, the connections to one "generator" being reversed from the normal "in-phase" output condition (pickups with three terminals are suitable if "out of phase" outputs are provided). One loudspeaker, too, must have its connections reversed to restore correct phasing.

More details are given in "A Two-Way Stereophonic Amplifier" by B. B. Bauer, J. Hollywood and G. Maerkle in the October 1958 issue of *Audio* and further reference is made to phantom operation in "The Bi-Ortho Output Circuit" (C. Nicholas Pryor), *Audio*, November, 1958.



RELATIVITY

By "CATHODE RAY"

1. All Observers are Equal (and none more equal than others)

Nature, and Nature's laws, lay hid in night:
God said, *Let Newton be!* and all was light.
Pope

It did not last: the Devil, howling *Ho!*
Let Einstein be! restored the status quo.
Squire

In the early 1920s, Einstein's Theory of Relativity was a music-hall joke—the supreme example of the incomprehensible. Even scientists had declared it unintelligible or absurd, or both. But their clamour died down somewhat and became more thoughtful when certain astronomical tests proposed by Einstein were carried out and the results of all agreed with his predictions, contrary to "classical" theory. Nowadays the consequences of the theory are not confined to a few minute astronomical discrepancies but are an everyday laboratory experience, and its truth is accepted without question. (Though in fact I did come across a book dated as late as 1932 which asserted at great length that relativity is bunk, but this could perhaps be regarded in the same class as utterances from the Flat Earth Society.)

So much is the theory of relativity taken for granted that I have from time to time referred to

Fig. 1. The wavelength and frequency of waves observed at O depend on whether the source remains at A or moves steadily from A to B, but their speed remains the same.

"the relativistic increase of mass" without being uneasily conscious of elevated eyebrows and furrowed foreheads. But perhaps I have been too insensitive. Anyway, if Ohm's law is not too obvious and established for re-examination, Einstein can hardly be taken as read.

There are two Einstein theories of relativity—the special and the general. The special theory concerns things in a state of uniform motion, and to the ordinary person is astonishing but not too difficult to follow. It can be worked out with quite moderate mathematics. The general theory includes the special and goes on to bring in non-uniform motion and gravitation. The beginning is quite easy, but all except the brighter mathematicians tend to fall out when the detailed working is being expounded.

The starting point for both is the recognition that in all the universe there is no fixed reference from which things can be measured. So everthing is relative.

Perhaps the biggest step towards this was taken a few hundred years ago, when the idea that the earth was fixed was gradually overthrown. We now know that the earth moves in a number of different ways—around its own axis; around the sun; along with the whole solar system away from the centre of the galaxy; and probably sharing an outward movement of the galaxy itself. If there were such a thing as a fixed point anywhere there would be no means of identifying it as such, so one may well question whether the idea has any meaning.

The last hope was the aether. This was the invisible and intangible medium that was supposed to exist everywhere, as something to carry light (by which word I am going to mean all electromagnetic waves) about the place. Waves being periodical changes of state, it is admittedly difficult to see how they could exist in empty space, which has no state to change. So the aether was invented for that express purpose. Its density and elasticity were calculated by analogy with other kinds of wave medium, and it turned out that it had to be immensely stiff, yet filling all space (including that occupied by solid bodies) and offering [illegible]esistance to movement. If it existed at all it wou[illegible]ve to exist throughout the universe (since lig[illegible] detected from sources of the order of 10^{22} miles away) so presumably it could be regarded as a stationary background to all the movements of worlds and men. It should therefore enable such movements to be measured absolutely instead of just relatively to some other moving thing.

The problem was to make contact with it. Its sole activity being as a medium for light, the only way of doing so was to measure the speed of light in various directions. The same kind of thing can be done in measuring the direction and speed of wind. If we discovered that sound travelled from A to B in 1.000 sec. and from B to A in 1.016 sec, then we would reckon that through still air it would take 1.008 sec*, and that the 0.8% gain in the A-to-B direction was due to a wind whose component of velocity in that direction was 0.8% of the normal 1100 ft./sec. at which sound travels through air, namely 8.8 ft./sec. or 6 m.p.h. As it seemed probable that the speed of the aether "wind" relative to the earth (caused by movement of the earth through it) might be very small compared with that of light, very precise methods of comparison were judged necessary; and from 1881 onwards Michelson and Morley carried out a famous experiment to compare the velocities of light in different directions. It revealed no aether wind. Only last week I saw news that this result had been confirmed by experiments with a precision of 1 in 10^{12}. That would have been sufficient to detect the earth's "aether speed" as low as one thousandth of its speed around the sun. It didn't detect any.

The physicists, who by 1881 had convinced themselves of the necessity for an aether, were reluctant to abandon it, and had to invent all sorts of explanations for the failure to detect an aether wind. With one exception, these all broke down. The exception seems even now to the non-scientist something quite fantastic invented specially to explain an awkward experimental result. It was that everything, including of course the measuring appara-

*There is a slight error here, quite negligible for the purpose, but important in measurements with light.

tus, shrinks in the direction of motion, to exactly the extent needed to offset the difference in the speed of light. The physicists of the time must have been very tenacious in their hold on the aether not to have let go there and then rather than accept such an explanation. As it happens, belief in the aether has since had to be abandoned for other reasons, so one might heave a sigh of relief at not having to fall back on such a far-fetched alternative. Yet the Fitzgerald or Lorentz contraction (as it is called) is now accepted as part of the theory of relativity, exact numerically but differing in viewpoint.

So even if there were an aether we would be unable to make use of it as a stationary reference for measuring absolute speeds. Whether it exists or not, the last hope of a fixed reference fails. Nobody can say " I am stationary, so my view is right and it is you who are moving ". All observers' views are equally valid. The laws of nature must be the same for all. That is the principle of relativity.

The one thing that happens in empty space is light (electromagnetic radiation). And where emptiness is complete there is no likelihood of light travelling at different speeds in different directions. The only way in which sound waves can come to us at different speeds is by wind; that is to say, a movement of the whole sound-carrying medium itself. But that doesn't apply to light, which has no medium —or, if you insist that it has, one whose relative velocity is inherently unmeasurable.

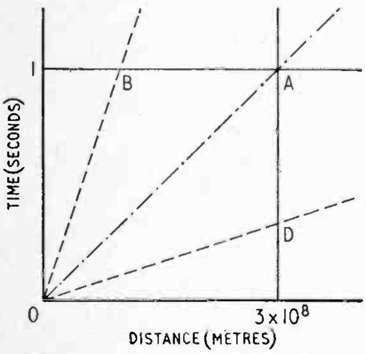


Fig. 2. Graph of time against distance, in which movements relative to some point show as sloping lines; straight lines for constant speeds. OA represents the progress of a beam of light, and OB of a point moving at one third the speed of light. The same line OB is the zero-distance axis of a graph applicable to that moving point. OD is the corresponding zero-time axis if the indicated speed of light is to be the same as for the first point.

Remembering the modern ideas about light being streams of photons, you might suppose that when the source of a light is coming towards us the light would be moving past us faster than when the source is retreating. That would certainly be so with bullets from a machine gun on an aircraft. But observations on the stars show that it makes no difference to the speed of the light from them whether they are moving towards or from us.

One can get quite confused between this and the Doppler effect, by which light changes colour (indicating a change of frequency) when its source is moving. This is applied in some radar systems, including those used by police to detect breaches of the speed limit. And the equivalent in sound is heard as the familiar fall in pitch of the locomotive whistle as it goes past at speed. But these changes in frequency are not due to changes in the velocity of the waves (in still air) but changes in wavelength due to differences in the positions at which start and finish of each wave are emitted.*

So c, the speed of light, is the same everywhere in space. Does that sound to you quite reasonable but not exceptionally interesting? If so, think about it again, alongside the other fact that no one observer can claim priority over others. Wouldn't it surprise you if you were on a platform watching a train coming in and found it made no difference to the speed of the train *relative to yourself*, whether you were standing still or running towards or away from it? Considered in this way the statement that the speed of light (in space) is the same for all observers seems quite absurd. Yet it is what we are driven to by the most precise experiments and by the absence of any basis for deciding who is stationary and who is moving. Is there any way of making sense of this fact that two observers moving relative to one another in the direction of a source of light both arrive at exactly the same figure for the speed of the light relative to themselves?

Speed, of course, is measured by dividing distance by time. We are accustomed to assuming that distance and time are both absolute quantities. For instance, if I say something is a foot long and you say it is 13 inches, then it would follow that at least one of us must be wrong. Time is a little trickier, because we are used to the idea of crossing over the International Date Line and finding ourselves back in yesterday. But of course time is not really altered merely by pulling leaves off a calendar. If I were to time an event and say it took 12 minutes and you said it took 13, then it would follow that at least one of our watches must be running fast or slow.

Presumably. But Einstein showed that in these matters we presume too much, and that distance and time are not absolute quantities but only relative. The arguments are put quite simply in his own books and in others (such as " The Laws of Nature " by R. E. Peierls) so I won't waste the remaining space repeating them but will show what is not so often explained in simple books—how, granting that time and distance are not absolute, they have to vary in order to preserve the absolute and unvarying nature of c.

Let us make a graph of these two quantities, distance and time; and having admitted that they are merely relative quantities we must give them precise meaning by specifying them relative to ourselves (supposed to be all together in one place). Fig. 2 shows a corner of such a graph. I have chosen the scales so that a ray of light whose velocity we are measuring would be plotted as the line OA. That line, as you see, tells us that the velocity is 300,000,000 metres per second (very nearly).

It happened that while we were timing the light over a distance we had carefully measured we noticed another group of observers who appeared to be flying in the same direction as the light at one third of its speed. So we plotted them too, as the line OB.

*For instance, if a source of waves remains at A in Fig. 1, the length of each wave is still the same when it arrives at an observer O. But if the start of the wave is emitted at A and the finish at B, the length as observed at O is shorter by the distance AB, and the frequency therefore higher.

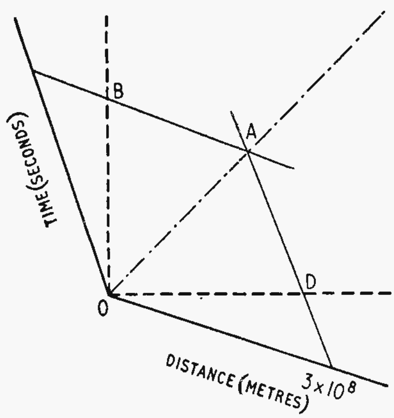


Fig. 3. Here the dotted axes in Fig. 2 are drawn at right angles to one another, as they would be by an observer at the Fig. 2 moving point. The original " fixed " point's axes are shown in solid line as before.

If we had forgotten for a moment the absoluteness of c and the relativity of time and distance, we might have thought that as the other observers were travelling along the light beam at one third of its speed the light would appear to them to be travelling at only two thirds of our c. But what we have to remember is that the measurements being carried out by the others must (if equally accurate) be showing them that the same light is travelling relative to themselves at the same rate, c, and that we are flying against it at $\frac{1}{3}c$.

The line OB on our graph, which to us represents their moving position, represents to them their own fixed position, or their zero distance (which they would naturally represent on their graph by a vertical axis through O). If their time levels were the same as ours—the horizontals through 0, 1, etc.—they would reckon that the light did the distance represented by BA in 1 sec, which would make their figure for its velocity one third less than ours.

This error can be avoided by making their time levels slope upwards; for example, their time zero would appear on our graph as OD Then lines drawn parallel to OB and OD, at equal distances from them, to represent 3×10^8 metres and 1 sec respectively (or any other quantities in those proportions) would intersect somewhere on OA, which we are agreed must be common to both graph systems, since it represents the common velocity c.

Stepping aboard the other observers' space ship as it flies past, we would now disapprove of the distorted axes OB and OD in Fig. 2 which we previously attributed to our new observation post, and would redraw them as in Fig. 3. We would note how ingeniously our erstwhile friends (now seen to be flying at 10^8 metres/sec against the light) manage to arrive at the same value of c as we do, in spite of—or by means of—their distorted axes.

But what about filling in some graph scale lines to represent what we now regard as (for example) 3×10^8 metres and 1 sec? We know they should be parallel to our dotted zero lines, but how far away? If we were thinking only of ourselves of course we could choose any scale that suited us. But we want the diagram to be applicable to both lots of observers.

Directly we try this problem we find how right we were to abandon such old-fashioned ideas as that a yard is a yard wherever you are. For if we mark off along our new distance scale OD a length equal to that representing 3×10^8 metres on the original scale, and draw a dotted line through it parallel to OB, the results are altogether different according to whether we use Fig. 3 or Fig. 2. In particular, in Fig. 3 the length OD, which according to the old scale represents 3×10^8 metres (because it is on the 3×10^8 full line) is seen from our new viewpoint to be considerably shorter than that;w hereas in Fig. 2 the new 3×10^8 line cuts OD to the left of D, so that the old 3×10^8 distance looks a little longer.

Even modern science isn't as crazy as all that, and the only new line that makes any sense at all is FEA′ in Fig. 4. We find we can draw its equivalent in Fig. 2.

In both diagrams OD, which would be read as 3×10^8 metres on the old scale, is shorter than our new 3×10^8 metres. And if we reckon by the old scale we see that the 3×10^8 dotted line cuts it to the left of the 3×10^8 mark, so by that standard the new 3×10^8 metres looks shorter. So both lots of observers agree in thinking that the other lot are overestimating their distances, or else for some reason connected perhaps with the fact that they are travelling at high speed the dimensions of their vehicle and all their measuring rods have shrunk along the direction of motion.

For this agreement to be perfect, so that the principle that all viewpoints are equally valid for such observations is fulfilled, the shrinkage must be the same for both. That stipulation fixes the spacing of the dotted distance lines. That is to say, in Fig. 4 the ratio DO/EO must be the same as FO/GO.

On the same principle we can draw time lines, as for example the new 1-sec line in Fig. 4. This shows that a period of time declared by the full-line people to be 1 sec. (OB) is seen by the dotted line people to be somewhat less, so according to them the watches used by the full-line people are running slow.* And precisely the same conclusion is drawn by the full-line people about the dotted-line people's watches.

If you are thinking that these peculiar views

*Or, looking at it another way, when the full-line people see their own watch pointing to 1 sec after zero, it is later than that on the dotted-line watch.

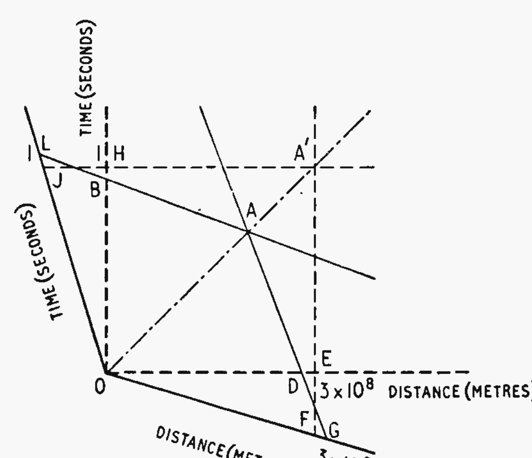


Fig. 4. Fig. 3 is here extended to include the only 1 sec and 3×10^8 metre lines that make each point's view of the other the same.

probably result from failure by the observers to allow for the time taken by light to communicate to them the readings of a watch at widely and rapidly varying distances, let me assure you that observers skilled enough to make such difficult measurements with high precision wouldn't overlook an elementary detail like that.

We now see (I hope) how it is possible for everyone in the universe to agree about the speed of light. They can do so by giving up the idea of time and distance being absolute quantities and admitting that the amount of either depends on the point of view. When things are moving relative to us, by our standards their distances are less and their timepieces are slow.

The next question is, How much less and how much slow? We have seen that the conversion factor from one viewpoint to the other is the fraction DO/EO (or FO/GO) for distance, and BO/HO for time; and the symmetry of the diagram makes these equal. Let us denote this shrinkage factor, or time-slowing factor, by α. It is not hard to see that it depends on the fraction of the speed of light with which the two viewpoints are moving relative to one another. We can call this fraction v/c, or for brevity β. Then α, which is what we want, can be related to β by means of the diagram for either viewpoint (Fig. 2 or Fig. 4), and the answer is the same either way. Let us use Fig. 4.

To avoid confusion I have repeated the relevant parts in Fig. 5, and have added a perpendicular GK from G to OE continued. Now we drew the diagram so that the velocity ratio β is represented by $\tan\theta$. That is,

$$\beta = \tan\theta = \frac{FE}{EO} = \frac{GK}{KO}$$

So $$KO = \frac{GK}{\tan\theta} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Likewise $J\hat{O}H = \theta$. And since we drew DG parallel to JO, and GK parallel to HO, $D\hat{G}K$ is also equal to θ. So

$$\frac{DK}{GK} = \tan\theta$$

and $$DK = GK\tan\theta \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

We have $$\alpha = \frac{DO}{EO} = \frac{FO}{GO}$$

and (because EOF and KOG are similar triangles)

$$\frac{FO}{GO} = \frac{EO}{KO}$$

So $$\alpha^2 = \frac{DO}{EO} \times \frac{EO}{KO} = \frac{DO}{KO} = \frac{KO - DK}{KO} = 1 - \frac{DK}{KO}$$

Substituting in this from (1) and (2),

$$\alpha^2 = 1 - \tan^2\theta = 1 - \beta^2$$

and $$\alpha = \sqrt{1-\beta^2} \text{ or } \sqrt{1-\frac{v^2}{c^2}}$$

This is part of what is known to science as the

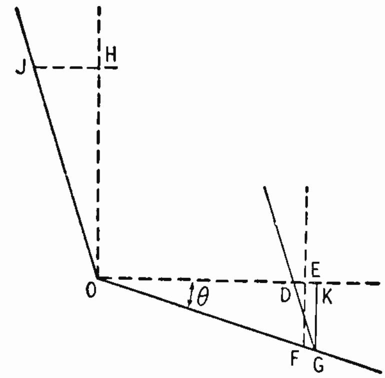


Fig. 5. Part of Fig 4 is repeated here, plus GK perpendicular to OE, for deriving by geometry the conversion formula from either viewpoint to the other.

Lorentz transformation. The same kind of formula applies to time.

If $v = 0$, which means that there is no relative motion between observer and observed, $\alpha = 1$, so there is no shrinkage or time slowing. Even if $v = 3{,}000$ km or about 1,865 miles per second, α is 0.99995, which wouldn't look very different from 1. But as the speed of light is closely approached the difference becomes very marked, and if we could see a watch travelling (relative to us) at the speed of light we would notice that its dimensions in the direction of motion were zero and it would appear to have stopped, though its owner (travelling with it) wouldn't see anything abnormal about it.

Besides the technical difficulties that may occur to you about making such observations, there is the additional one (which we shall consider next month) that the watch—and its owner—would be infinitely heavy! So that particular experiment is rather out of the question. In fact you may be thinking that any experiment which would show an unmistakable shrinkage or slowing is out of the question and so is the whole fantastic theory.

If so, you may be interested in a line of research quoted by the aforementioned Prof. Peierls in his "The Laws of Nature" (p. 263). Certain particles called mesons, produced by primary cosmic radiation at about sputnik height in the upper atmosphere, have a lifetime of only about 2 microseconds, yet manage to reach the earth. If you work it out you will conclude that to do it in their lifetime they would have to move at hundreds of times the speed of light. But that is agreed by all to be impossible. Their speed is in fact only very slightly less than c. So (as you will see from the transformation formula) the relativity effects are large. It appears that an observer travelling with a meson would confirm that its lifetime was 2μsec, but to us on the ground his watch would be running very slow indeed and by earth time we would make it nearer $2m$sec, allowing ample time for the journey. The meson-based observer would have hundreds of kilometres of atmosphere (by our standards) rushing past him at nearly the speed of light, but being subject thereby to drastic shrinkage the distance would be traversable within the 2μsec lifetime.

It is fair to mention that Prof. Cullwick has (in his "Electromagnetism and Relativity") greeted this support for the theory of relativity with some scepticism. I can't help feeling a little dubious about it myself, for if one takes it to its logical conclusion by applying it to photons, which (being light) not unnaturally travel with the speed of light, then it appears that with a photon's-eye view all distances in the direction of motion, however great—even millions of light years—have shrunk to nothing; in other words, a photon has no need to travel anywhere because directly it starts it is already there! Which is very convenient for it, and might seem to provide an answer to the problem of how light gets across empty space! If there is a physicist in the house perhaps he would kindly come forward and state whether this is indeed implied in the special theory of relativity, or if there is a fallacy, and if so where.

That nothing can ever exceed the speed of light follows from the Lorentz transformation, because values of v/c greater than 1 lead to imaginary quantities. So we can never break the light barrier—in empty space. But in air, light travels very slightly slower, and in glass and other transparent solids and liquids it travels considerably slower. There, the light barrier can be and frequently is broken, for example by high-speed electrons. The result is not the interesting and (to glasshouse owners) destructive bang that accompanies the breaking of the sound barrier, but an interesting (and apparently harmless) blue glow. It is known as the Cerenkov effect, after the Russian scientist who, with two colleagues, was recently awarded a Nobel prize for researches into it. Incidentally, this effect is analogous to what goes on in the now much used travelling-wave tubes, in which a beam of electrons is fired through an artificially-slowed electromagnetic wave path.

Although the strange effects of relativity on distance and time do show up directly in some modern experimental work, they are for the most part a little outside our scope. But mass and energy are also involved, and they touch us more closely. So that is to be the subject next month.

BOOKS RECEIVED

Radioastronomy and Radar, by J. G. Crowther. Short account of the development of radar and of the techniques used in radioastronomy written for the layman and illustrated by photographs and simple drawings. Pp. 64; Figs. 58. Price 10s 6d. Methuen & Co., Ltd., 36, Essex Street, London, W.C.2.

The Face of the Sun, by H. W. Newton. General account of solar activity and accompanying terrestrial manifestations. Includes a chapter on the ionosphere and the emission of radio waves by the sun. Pp. 208; Figs. 37 and 16 plates. Price 3s 6d. Penguin Books, Ltd., Harmondsworth, Middlesex.

Magnetic Recording Techniques, by W. Earl Stewart. Deals with the properties of magnetic materials, the recording process and the design of recording mechanisms, mainly for use at audio frequencies, but with some reference to unconventional methods, such as boundary displacement and flux-sensitive heads. Pp. 272; Figs. 205. Price 66s. McGraw-Hill Publishing Co., Ltd., 95, Farringdon Street, London, E.C.4.

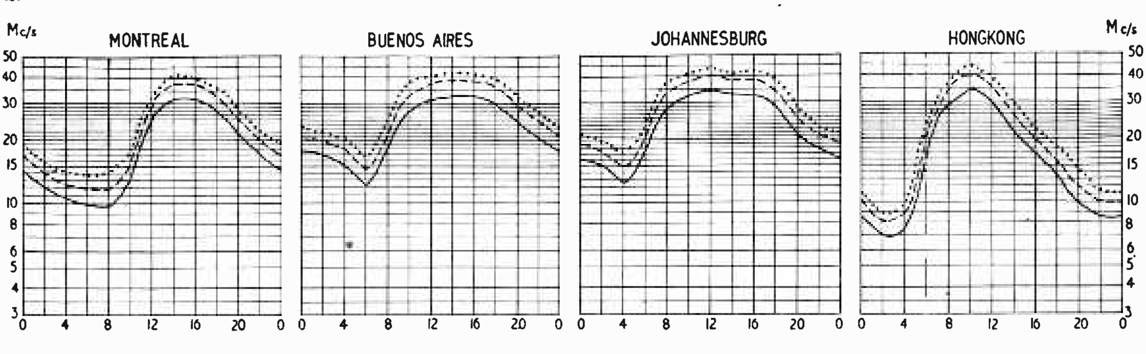
Television Servicing Handbook, by Gordon J. King, Assoc. Brit.I.R.E. Starts with each fault symptom and sets out in logical sequence the appropriate action to locate and remedy the trouble. A practical book indicating useful servicing short cuts as well as the basic theoretical background. Pp. 280; Figs. 165. Price 30s. Odhams Press, Ltd., 96, Long Acre, London, W.C.2.

Telecommunications, by A. T. Starr, M.A., Ph.D., M.I.E.E. Second edition of textbook covering the syllabus of Telecommunications in the London University degree courses. Pp. 470; Figs. 427. Price 37s 6d. Sir Isaac Pitman & Sons, Ltd., Parker Street, London, W.C.2.

Signal Generators, Attenuators, Voltmeters and Ammeters at Radio Frequencies. "Notes on Applied Science No. 19" issued by the National Physical Laboratory, D.S.I.R., describe the equipment and procedures recommended and used at the N.P.L. for calibration. Pp. 16; Figs. 6. Price 1s 6d. H.M. Stationery Office, Kingsway, London, W.C.2.

SHORT-WAVE CONDITIONS

Prediction for February



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 February.

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

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

— — — PREDICTED AVERAGE MAXIMUM USABLE FREQUENCY

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

A Television Prompter

By R. C. WHITEHEAD, A.M.I.E.E.

IT is well known that television news-readers and artists sometimes require inconspicuous aids to supplement their memories, and this has caused a type of rolling caption to be employed in the studios. These rolling captions are prepared in a special typewriter, having characters about ½in high, and a display measuring about 9in × 7in is mounted just above the lens of each camera. Separate scripts are provided by carbon copies, and these are kept running in synchronism with each other by means of contacts operated through sprocket holes in the paper. An operator regulates the speed (and on rehearsal the direction) of transport of the scripts from a control console.

As this system has certain disadvantages, the writer has devised an alternative. This consists of a strip of paper 3½in wide bearing *conventional* typescript and transported in front of an *industrial* television camera, the displays taking place on television receivers operated from the r.f. output of the industrial camera. There is no need, of course, to make carbon copies of the script.

Separate scripts are joined together by means of a glue pen, but provision has also been made for jointing by means of staples, which are located outside the typing width and pass through suitable troughs in the script transport channel. An area of about 2in × 1½in is scanned by the industrial camera. In order that the operator may select a particular point in the script at which display commences, the pressure plate holding down the script is made of Perspex.

As in the original equipment, a movable pointer is provided on the left-hand side of the scanning aperture to indicate that particular line of the script which the artist should actually be reading.

Television camera tubes should not be used pointing downwards, owing to the danger of pieces of oxide coating falling from the cathode on to the photo-electric target. The script is therefore scanned via a small mirror set at 45° to the horizontal plane, the camera being mounted in the normal horizontal position. (This necessitates reversal of the frame-scan coils in the camera.) A 2-inch *f*1.9 lens is employed, operated normally at about *f*2.8. The script is illuminated by means of a 24-watt car bulb mounted immediately below the lens, and the normal high-light brightness is 250 foot-lamberts.

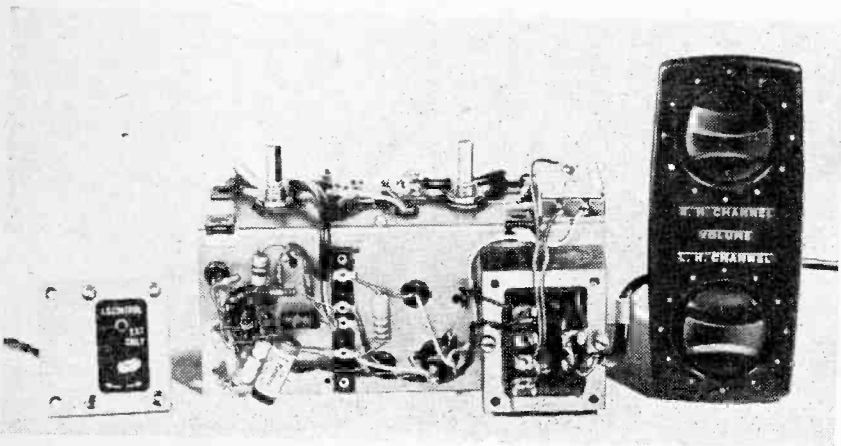
If a fully illuminated caption is left stationary in the scanning aperture for a long period, a permanent impression may be left on the camera tube, and to guard against this the lamp is dimmed until the script is driven.

The display receivers may be mounted on the stands of normal studio cameras. With static cameras the receivers may be placed on stands and viewed through large vertical mirrors mounted on the cameras and set at 45° to the axes of the latter. Experiments conducted by the writer suggest that an angle not exceeding 4° should be subtended by the two straight lines joining the performer's eye with the centres of the camera lens and display tube.

For the writer's instrument, designed specially for television news work, the following advantages are claimed over earlier systems:—

1. No special typewriter is needed.
2. Only single rolls are loaded into the typewriter, and finally into the scanning unit.
3. Corrections need only be made on the single copy.
4. There is no danger of loss of synchronism between various displays.
5. For long programmes the problem of script storage is considerably eased.
6. The operator can see passages both before and after that being displayed.
7. Displays of different sizes may easily be arranged.
8. The instrument is much quieter in operation.

Finally, the writer wishes to acknowledge the interest of Independent Television News, Ltd., in this work.



Stereo Conversion Kit

For converting Ferguson 389RG and 601RG radiograms to play stereophonic records, a second independent audio amplifier (with power supply) is provided in their type STA/1 unit shown in the illustration. An ECL82 triode-pentode provides amplification in the triode section and three watts output from the pentode.

Cooling Airborne Electronic Equipment

By L. A. WILLIAMSON,* A.M.I.E.E.

USE OF LIQUID CIRCULATING IN CHASSIS WALLS

THE cooling of electronic equipment in high-speed military aircraft has become a problem of such importance that it must be considered at the aircraft-design stage. Inefficient cooling systems impose on aircraft needless weight and burdens in fuel consumption, burdens whose origins lie in the electric and aerodynamic loads created by excessive cooling demands.

Aerodynamic-heating effects, associated with ever-increasing flight speeds, result ultimately in the air, to which electronic equipment hitherto transferred waste heat, becoming no longer economically suitable either as a heat-transporter or as a heat-absorbing sink. This article introduces the possibilities of developing simple liquid-cooling methods, thus offering an attractive and efficient means of meeting the primary problem of transporting unwanted heat away from electronic equipment; the waste heat is ultimately removed by a heat-exchanger which must, for any cooling system, necessarily be provided as an aircraft service

Two promising techniques, in which the chassis itself becomes an air/liquid heat-exchanger, are described and attention is drawn to the ancillaries necessary to any closed-circuit liquid-cooled system. Improvements in thermal efficiency and thermally segregated layouts are not considered because their benefits are inevitably long-term and marginal compared with the need for greatly improved cooling efficiencies.

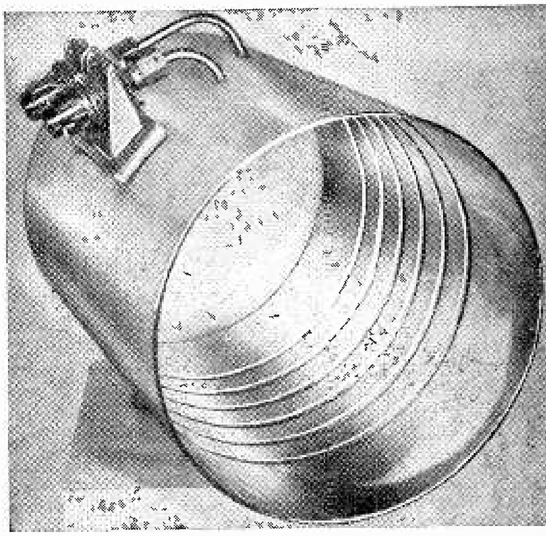
History of Cooling Methods.—Under flight conditions in World War II, equipment cooling was hardly ever a problem. Most electronic "boxes" were of open construction, altitudes were not great and the decrease in air temperature with an increase in altitude was often more than adequate in balancing out any overheating tendencies. Flight through cloud often caused water to appear in the "cooling system" and this was troublesome.

Progress since the war on electronic aids has, in its turn, increased the problem of the removal of unwanted heat from the aircraft. The factors responsible are:—pressurization (necessary to counter flash-over and moisture troubles) which has become almost universal for British military radar; higher heat losses per unit area due to the weight- and space-saving advantages of miniaturization; greater use of electronic aids; greater working powers; and, more particularly, the rapid advance in aircraft performance resulting in higher equipment-bay temperatures, lower air densities and aerodynamic heating.

In high-speed flight, adiabatic compression of air due to the forward passage of the aircraft causes a temperature rise roughly equal to $(v/100)^2$ °C (v in m.p.h.). The air taken inboard for cooling increases in temperature with increasing flight speed until eventually it becomes hotter than the equipment to be cooled. If flight at a supersonic speed continues for any length of time, the temperature of the aircraft structure will rise, heat will flow into equipments and even static components and materials will exceed their own temperature limits. It is well known that +55°C is about the maximum ambient temperature which can be allowed for current military electronic equipment and this temperature could be attained by the air at about 825 m.p.h. (Mach 1.25)—at Mach 2 (1,320 m.p.h.), it would be about 150°C.

About ten years ago equipment cooling was more or less fortuitous in that natural convective and radiation losses to the aircraft structure and thence to the outside air combined favourably to avoid overheating of most equipment. In time, pressurized units were fitted with internal fans (later external), circulatory systems and then double wall pressure cans, often containing an air-to-air matrix for forced-convective cooling. The cooling air for very many present-day equipments is obtained from a scoop in the aircraft fuselage which is connected by ducting to the equipment bay; ram-air enters the scoop, passes over the equipment (or simply into the bay) and thereafter spills to waste. Scoops have limiting pressure heads, ducts involve pressure losses, and, largely due to the reduction in air density with increasing altitude (at 60,000ft about

* Royal Radar Establishment, Malvern.



Part-fabricated pressure-can with ducts formed on one side only. This may be used as a replacement pressure-can for existing equipment suffering from overheating due to operation outside its altitude range.

10% of its sea-level value), the mass flow of air available usually falls far more with altitude than can be compensated by the fall in temperature with increasing altitude (about 2°C per 1,000ft, levelling out at −56°C above 37,000ft).

Improved sources of cooling air (e.g., low-pressure blower, expansion turbine, engine compressor-tapping and regenerative heat-exchangers) together with individual radars with well-designed air cooling systems are now appearing. Even so, overall cooling efficiencies can be very poor; at high altitude considerable power is necessary to supply an adequate mass-flow of air to maintain a typical unit dissipating, say, 300W at a safe working temperature. If in this situation the air becomes no longer available (except by the expenditure of more work, and hence more fuel, into a heat-pump system), other means of cooling must be explored.

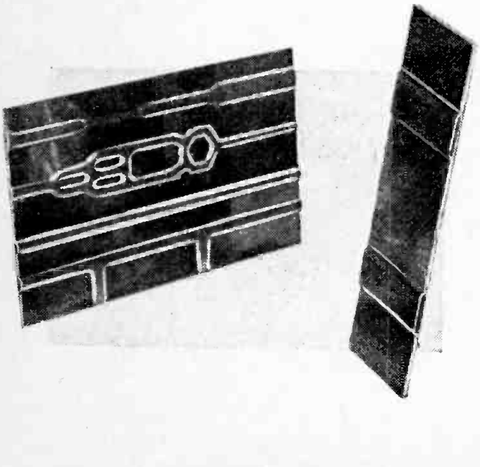
Liquid Cooling.—The more practical possibilities are:—expendable methods utilizing the latent heat of vaporization, and requiring no heat-absorbing sink; closed-circuit methods using liquid coolants and refrigeration cycles using a high-temperature refrigerant.

Two closed-circuit coolant methods are possible and differ only in the means used for transferring heat from the electronic equipment. Each uses a pump to circulate a liquid through the electronic equipment, where it takes up heat, and a heat-exchanger, where the heat is removed. This exchanger probably would be air-cooled initially; although it seems reasonable to suppose that ultimately it would be fuel-cooled.

In one method, the electronic equipment is housed in a liquid-tight container which is then simply filled with a heat-transfer fluid of good dielectric properties; a typical British unit would have its weight doubled and the tedious business of draining-off and drying-out, for even the most minor attention inside, would find no favour in the Armed Services.

The other method utilizes a heat-exchanger inside the unit, no wet contact being made between the electronic equipment and the coolant; as this circulates through the chassis itself the cooling is indirect and depends mainly on conductive- and convective-transfer modes. The exchanger techniques adopted provide reasonable flexibility in the construction of "hardware" and for the liquid side to be usable readily either in a simple closed coolant-circuit or in a high-temperature refrigerant circuit (a heat-pump application under long-term consideration).

Two small pieces of ducted aluminium chassis. Left-hand example shows complex duct formations possible and right-hand section is inflated on one side only.



The essential components of an air/liquid system necessary to maintain a radar at some optimum temperature up to, say, 120°C are given in the accompanying diagram which shows a series flow for two units, one unit having much less waste heat than the other (a frequent arrangement). Clearly, whether a series or parallel flow is desirable must depend on the merits of a particular system—e.g., several boxes of comparable dissipation would almost certainly require parallel flow. Some units in a system (e.g., junction boxes, power units) could operate at higher temperatures than others; but then pressure losses might become the deciding factor.

It is worth emphasizing that any component used in a liquid-coolant system, apart from meeting normal aircraft-design requirements, must meet the temperature-range limits of −40°C up to about +120°C and be acceptably compatible with the materials used in the system.

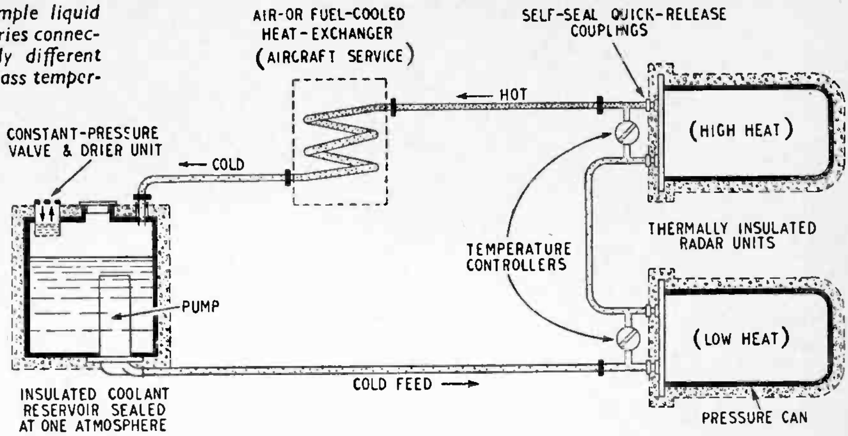
Heat-Exchanger.—A simple air/liquid heat-exchanger fitted to a unit would undoubtedly promote considerable improvements in cooling efficiency but, in addition to added weight, two drawbacks arise—one, rarely being able to find room for retrospective modifications, the other difficulty being the achievement of thermal segregation without a complex layout.

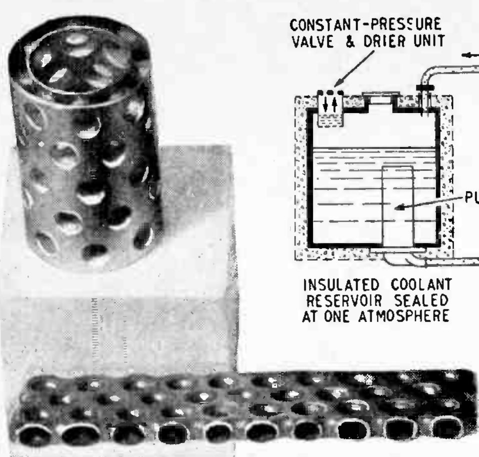
Here we are interested only in the development of techniques which have early practical applications and enable the chassis itself to utilize the obvious advantages of being the heat-exchanger. Originally, no suitable material was readily available for forming matrix and chassis; sheet-metal fabrication was not seriously considered since it seemed important to keep joints, and thus fabrication difficulties and leakage risks, to the minimum.

Some early experiments in electroforming matrix valve-screens resulted in attention being drawn to a promising electroformed-honeycomb process. The Ministry of Supply provided a contract for development work on this material, with particular interest in a seamless honeycomb nickel-electroform able to withstand 80 p.s.i. working pressure and an ultimate pressure of 200 p.s.i. With walls only 0.010 in thick the material developed was remarkably strong, very light in weight and with good heat-exchanger characteristics. Subsequent electroplating developments resulted in a virtually stress-free deposit being obtained from a nickel sulphamate bath. The actual matrix is made by electroplating over a metal mandrel of low melting-point, previously drilled and machined to a solid "negative" of the required chassis section. After electroforming, the mandrel is melted out and any traces of internal dross remaining are removed by chemical means to leave a perfectly clean internal surface.

Some time after the work on nickel honeycomb had started, roll-bonded, ducted aluminium sheet was introduced into this country for the refrigerator industry. This material, which is comparatively cheap and readily available, is being examined as a chassis material and appears to have considerable possibilities. The ducts are integral with the sheet and the pattern can be made to suit the component layout; sheets are available in thicknesses 10 to 16

Schematic layout for simple liquid cooling system. Note series connection of units with widely different heat generation, and bypass temperature control valves.





Integral valve screen and small section of chassis produced by the electroformed honeycomb process.

s.w.g. with an adequate range of duct section and duct pattern. (Present experiments utilize 16 s.w.g. material with $\frac{3}{8}$-in ducts. Duct volume has been 0.25 to 0.3 cc per watt overall—80 cc for 300W unit.)

The duct-ways are usually prepared by silk-screen printing the pattern required on one face of an aluminium alloy sheet and then roll-welding another sheet to it, face to face. Welding does not take place over the printed areas and the ducts can be formed by applying hydraulic pressure (800-1000 p.s.i.) to a temporary connection made by breaking into the pattern, either on the sheet edge or face. The duct walls work harden during the process and give excellent stiffening properties to the material.

Permanent inlet and outlet connections to the ducts may be made, either by cutting away panel material and utilizing a length of duct tube included in the pattern for this purpose, or by soldering or brazing a light alloy tube into a duct. Apart from the difficulties of joining dissimilar tube materials, light alloy is advocated at this point to minimize corrosion risk which would otherwise create a vulnerable junction in the coolant circuit. Adequate soft-soldering facilities are provided by chemical plating of the chassis with nickel. Another obvious application for ducted aluminium sheet would be liquid-cooled pressure-cans to replace conventional cans on established equipment which presents overheating problems; a relatively simple interim method of introducing liquid cooling is thus provided.

Insulation.—The need to restrict heat-transfer through the external surfaces of a radar unit arises where the "normal" condition of heat flow away from the equipment is halted or reversed due to high environmental temperatures. Under these conditions equipment and materials would rise in temperature above their permissible maxima unless means of cooling are provided, not only to remove all waste generated in the electronic equipment, but also to carry away the inflow from external sources.

It is not practicable at present to predict the parameters which would combine to cause sufficient inflow of heat to an equipment to make it overheat, because several unknowns are involved—e.g., thermal inertia (both of the aircraft and equipment), flight plan, time during which the equipment is operating, turn-round-time, equipment location within the aircraft, etc. (Present-day electronic equipment in a short-range fighter—ram-air temperature 150/200°C —may not necessarily overheat, while a long flight with ram-air temperature of about 80°C could cause serious overheating.) In fact the thermal characteristics of an equipment can only be assessed satisfactorily by means of chamber-simulated tests.

Two methods of restricting external heat flow into airborne radar units are being considered—thermal insulation and radiant-heat reflection. These are probably best described by application to a typical unit, the figures quoted being only sufficiently accurate to be illustrative. It is interesting to note that the external construction of present-day airborne radar units almost invariably takes the form of a light-alloy sheet-metal cylinder, domed at one end and arranged, at its other end, to form a pressure seal on a machined face of the front panel of the internal chassis; the unit is internally pressurized with air to about 20 p.s.i. (absolute).

A typical unit may dissipate 300 W of waste heat in a cylindrical container of dimensions about 20in long × 10in diameter and, in the highest temperatures generally associated with subsonic flight, its "can" temperature (as customarily measured on the outer face of the pressurized can) would probably not exceed 70°C. If an inch of thermal insulation—cork, felt, etc., is added to all external surfaces, approximately 90% of the internal waste heat must be removed (or the can temperature would run up theoretically to several hundred degrees Centigrade —and this would cause an all-round failure).

If this same insulated unit is now used in a high-speed aircraft where the environmental steady-state temperature is, say, 120°C and the can temperature held at 70°C by some cooling aid, the added inflow cooling load due to heat flow through the insulation would be approximately 30 W. Without the insulation, of course, the added cooling load would be quite impractical.

Unfortunately conventional insulation, although having a low thermal conductivity, is not, as far as weight and temperature range are concerned, a suitable material for use as an external lining to radar boxes—nor, even more important, does it lend itself as a constructional material for this purpose. In its place the use of glass-laminate sandwich construction, using epoxy or polyester resins, is being considered as a direct substitute for the metal pressure can and front panel. The thermal conductivity for a 1-in wall glass-laminate container would appear to lie between 1 and 3 BThU/ft²/hr/°F; this is about ten times greater than for conventional insulating materials: this would mean an inflow cooling load of about 300 W.

The other and more attractive method utilizes the considerable heat-flow restriction associated with polished surfaces. A pressure-can having a closely-encompassing, external, light-gauge aluminium jacket which need be only strong enough for handling purposes is visualized. Internal, external and mutually-reflecting surfaces would be of polished aluminium with an anodized finish. The pressure-can proper would be made in a clad alloy for structural strength with the jacket supported by plastic-laminate spacer rings: it may be necessary to vent the jacket annulus to avoid pressure differentials. Modern aluminium polishing is claimed to give an emissivity lower than 0.1 and, even with the hazards of normal usage, the reflecting properties should make, for the average type of unit described, an added cooling load of only about 15 W.

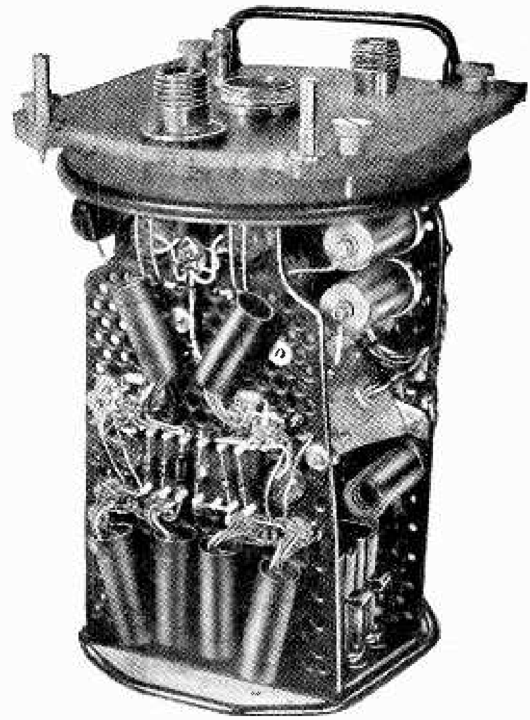
Both methods create constructional problems. The former offers robustness and requires little development work, but there are possible temperature limitations and comparatively high inflow loads; the latter offers weight saving, low cooling loads and no temperature problem, but requires a fair amount of development. It is possible that a combination of both methods may become necessary.

Ancillaries.—Quick-release terminations, which automatically seal on disconnection, are self-evident necessities for both the coolant hose and the equipment. Couplings so far used are off-the-shelf, aircraft hydraulic types and these have been satisfactory for laboratory experiments. Although no existing coupling is known to meet requirements, little development should be involved in meeting the ability to seal without leaks at the comparatively low working pressures of about 20 p.s.i. and the selection of body and seal materials compatible with the coolant used.

While fixed-installation coolant-pipe runs in the aircraft may be assumed to be of copper or light alloy, it is necessary, for maintaining anti-vibration facilities and for quick release, to make the final equipment connection in flexible hose. Aircraft-type, braided, synthetic-rubber hydraulic hose has for convenience been used so far; but this does not imply its compatibility with the coolant finally selected.

Small coolant pumps may have to be designed to suit the pressure losses and flow rates required for various systems. Our experiments have utilized an aircraft-type, submerged fuel pump rated at 100 gallons per hour, 15 p.s.i. pressure-head and consuming 120 W of drive power. Little development would be necessary to modify this type of pump to meet the requirements.

The coolant reservoir or header tank would have a capacity of a gallon or so and would need to be designed as a sealed unit to withstand a working differential pressure of about ±15 p.s.i. Altitude would create a positive pressure difference of up to about 14 p.s.i. and an "inverse-pressure fault" of the same order could arise in the event of a leak developing on ascent and becoming self-sealing on descent. If the reservoir is not sealed difficulties would be created in the unwanted boiling of the coolant at altitude and in moisture-absorption troubles to which some coolant fluids are prone. Thermal insulation of the tank would, of course, be necessary. Apart from the pump, other necessary components to be fitted to the reservoir tank would be a constant-pressure relief valve and drier unit, coolant-level indicator and filler cap. The relief valve is necessary to compensate for the pressure variations arising from the wide changes in temperature to which the coolant is liable.



Early honeycomb-type chassis. High-dissipation valves (wire connections only are visible) are mounted in the integral type of screen shown, detached from chassis, in other photograph. Coolant-hose connections are made to the two large screwed unions on panel. Whole chassis, without components, weighs only $1\frac{3}{4}$ lb.

The other main component needed is a simple bypass-type temperature controller. This requires development; but it is envisaged in a quite small unit, probably being mounted on the inside of the radar-unit panel or possibly combined with the inlet and outlet unions as a composite assembly. Its temperature differential could be quite coarse—possibly 10 to 20°C.

Choice of Coolants.—The properties required of any coolant fluid must be:—

(a) Mobility at any temperature between −60°C and +100/120°C; it need be fluid only above about 0°C.

(b) High flash and fire points with no explosion hazard.

(c) Little or no toxic tendencies.

(d) Low viscosity to keep pumping power down.

(e) Good heat transfer properties.

(f) Low corrosion and/or chemical action on the commonly-used aircraft materials, particularly light alloys and seal rubbers.

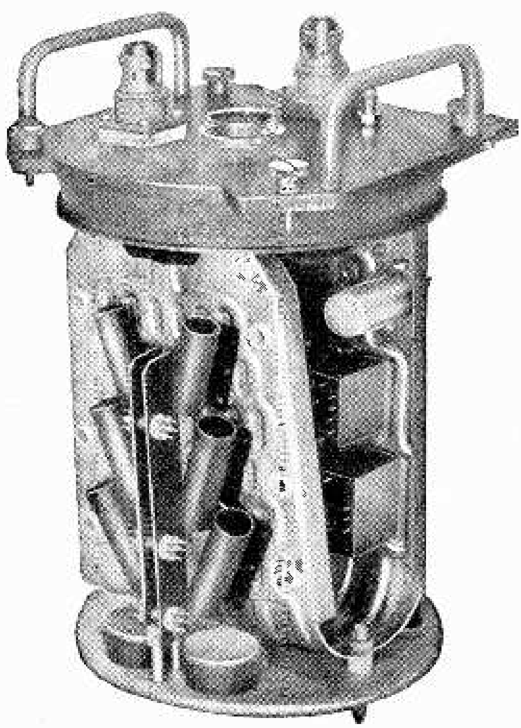
(g) Chemical stability.

Water has everything to commend it, except for the limited temperature range in which it can be used and for corrosion tendencies. Glycol-water mixtures have been used; but these create a greater corrosion problem, particularly on "mixed" metals and steels; it would be necessary to have a system manufactured uniformly in either plated copper or aluminium throughout.

Several synthetic fluids have been considered but the only fluid even having claims to meeting all requirements is a silicate ester-based fluid produced by Monsanto Chemicals, Ltd., and known as Heat Transfer Fluid RD6195. Experiments are in progress to assess the performance of this fluid in the chassis materials described earlier. The claims made include a temperature range of −65°C to +200°C with specific heat about twice that of air and half that of water, and thermal conductivity about four times that of air and a fifth that of water. Specific gravity is about 0.9 and dielectric strength is adequate.

Conclusions.—This article has not discussed improvements in thermal efficiencies because, on a short-term basis, little practical change can be visualized in the inevitable losses associated with components such as resistors, transformers, valves, etc. Transistorized electronic units, of course, offer considerable scope in the reduction of waste heat, although, until high-temperature transistors come into wide use, the cooling problem is likely to remain a major one.

Experimental ducted aluminium chassis before wiring. Note valve screens soldered to chassis and bayonet-type coolant hose unions.



Raising the working ambient temperature brings about an effective improvement in thermal efficiency. Although some components working up to 500°C may be available, it seems unlikely that a complete range of electronic components having working temperatures much in excess of 100°C will ever materialize. Thus, even with well-designed and segregated layouts, the maximum working temperature is unlikely to exceed 80 to 90°C.

While the disadvantages of a closed-circuit liquid-cooled system appear to be confined to some loss of flexibility in experimental construction and the almost negligible risk of leaks, the advantages expected from liquid cooling in general may be summarized thus:—

(1) Reduction in fuel consumption due to weight-saving in ducting, air-blowers, drag, generator capacity, etc.

(2) It is the only way yet known offering ready practical application to the cooling of electronic equipment in aircraft having performance much in excess of those at present in service.

(3) Greatly improved heat-transfer characteristics, particularly since heat can be taken into the cooling system virtually at its source.

(4) Improved reliability due to operation within much narrower temperature limits than has been hitherto standard practice.

(5) Greater thermal loading is possible.

(6) Thermal segregation is more readily achieved.

(7) The power expended in coolant circulation is a small fraction of that expended in some air systems.

(8) Small bore pipes are used, instead of large section air ducting.

(9) No special maintenance difficulties are involved.

Much experience in the use of integral-chassis heat-exchanger construction needs to be built up; but early experiments are sufficiently impressive to encourage development work on a much wider scale. The particular potential it offers to both airborne and ground equipment is simple and effective temperature control resulting inevitably in improved reliability.

Acknowledgment.—The author would like to acknowledge the work done by Mr. J. E. Green of the Royal Radar Establishment on integral-chassis heat-exchanger techniques.

B.B.C. Handbook

WITHIN its 280 pages the "B.B.C. Handbook" for 1959 presents a very comprehensive review of the past year's work of the Corporation in providing the national and external sound services and its television service. Amongst the useful reference material in the Handbook are facts and figures about transmitting stations (in which there are over 180 transmitters), programmes, licences and the B.B.C.'s income from them, and numerous tables, charts and maps. It is heavily weighted on the programme side but there is an interesting section covering the work of the various departments of the Engineering Division which employs a staff of over 5,000 —about a third of the Corporation's total. The Handbook costs 5s.

Alternatives to the Wien Bridge

With Modifications Giving Improved Characteristics

By J. F. YOUNG,* A.M.I.E.E., A.M.Brit.I.R.E.

WHEN a problem arises which was met and solved many years ago, one naturally uses the same solution. However, an occasional re-examination of some of these stock solutions does no harm; in fact it is often beneficial. One of these problems where almost everyone uses the standard approach is the design of a simple variable audio frequency oscillator. Most people want to avoid the use of multi-gang controls or at least to use as few gangs as possible. Consequently they finally decide on the Wien bridge circuit which appears to have been first used around 1930[1].

In the early days a true bridge was used with its supply from a transformer, but in later years designers have learned to release valve cathodes from the earth (e.g. refs. 2, 3, etc.) and use the selective part of the circuit in other ways, so that the transformer is no longer required. Today many, perhaps most, precision audio oscillators use this approach. In some precision decade oscillators it has been found necessary to compensate for the impedance of the source supplying the selective circuit and one way of doing this is given in references 4 and 5. Terman[6] pointed out that if variable capacitors are used rather than variable resistors, the input impedance of the selective circuit does not vary as the oscillator is tuned. This fact has been used in some commercial oscillators[7]. The effects of component tolerances have been discussed by Clarke[8] and of stray capacitance by Diamond[9].

*Switchgear Works, G.E.C. Ltd.

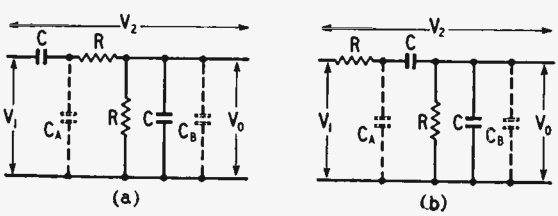


Fig. 1 The Wien half bridge.

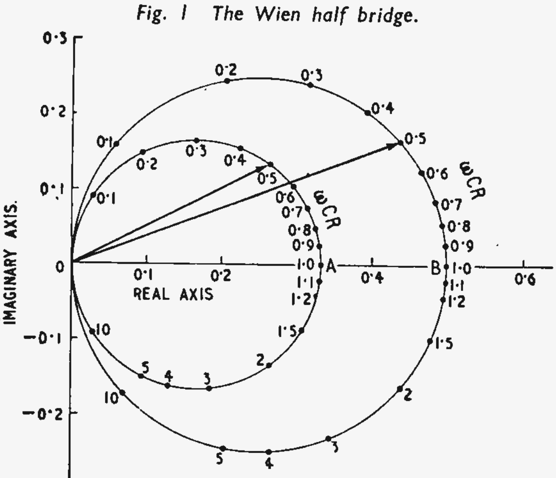


Fig. 2 Frequency response; A—circuit of Fig. 1; B—circuit of Fig. 7.

It will be seen from the above that a great deal of work has been done to find out the best way to use the Wien bridge in oscillators and to determine its characteristics under various conditions. Very much more work has been done on the actual design and construction of oscillators using the Wien bridge and many articles describing this work have been and are being published. This is all rather strange when it is realized that other circuits, rather simpler in form and more obvious in action, give exactly the same frequency response as the Wien bridge.

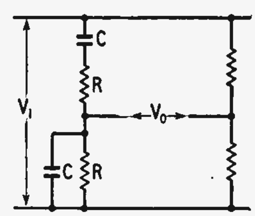


Fig. 3 Complete Wien bridge.

Basic Circuits

The basic half Wien bridge used in oscillators is shown in Fig. 1. The arrangement of Fig. 1(b) is often seen in oscillators, and at first sight it is exactly the same as Fig. 1(a). However, when the stray capacitances (shown dotted) are considered Fig. 1(b) has a disadvantage. By applying Thevenin's theorem to Fig. 1(a), it can be seen that the stray capacitance C_A simply adds some attenuation which does not vary with frequency and at the same time effectively appears in parallel with the input capacitor. Since the other capacitor has a stray capacitance C_B across it, the increase of the input capacitor by C_A is actually beneficial. On the other hand in Fig. 1(b), Thevenin's theorem shows that a frequency dependent attenuation is added by C_A, and C_A effectively appears across the input resistor. This upsets the frequency response of the circuit and the stray capacitances are introduced into the coefficients of the circuit equations in a rather more complicated manner than is the case for Fig. 1(a).

If the stray capacitances are not taken into account, the frequency response of either Wien half bridge is

$$\frac{V_0}{V_1} = \frac{j\omega CR}{1-\omega^2 C^2 R^2 + 3j\omega CR}$$

where ω is 6.28 times the frequency of V_1. This can be regarded as a vector and the locus of the tip of this vector as the frequency varies is plotted in Fig. 2. For the sake of generality, the curve is marked with values of ωCR,

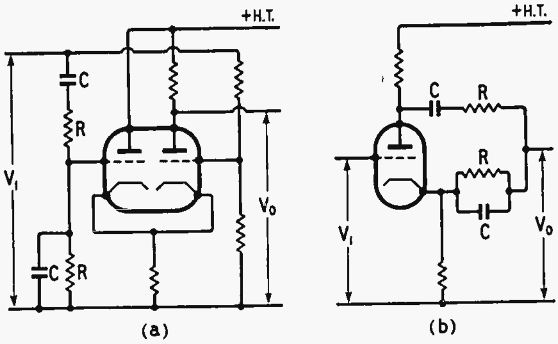


Fig. 4 Bridges with common input-output terminals.

rather than values of frequency. At a frequency where ωCR is unity, the output voltage is one-third of the amplitude of, and in phase with, the input voltage. Therefore if the network is placed in the positive feedback path of an amplifier, oscillation will tend to take place at a frequency where $\omega CR = 1$, provided the gain of the amplifier is greater than 3.

The rate of change of phase shift with frequency should be as large as possible at the oscillation frequency if the selective circuit is to have good control. Phase shifts in the associated amplifier then have a reduced effect on the frequency of oscillation. One way of improving the rate of change of phase with frequency is to subtract from the output of the network a voltage in phase with the input voltage. This can be done by use of a slightly unbalanced complete Wien bridge as shown in Fig. 3. This has the effect of moving the vector locus to the left. The attenuation at the oscillation frequency is then increased, but it is not difficult to increase the gain of the associated amplifier to compensate for this.

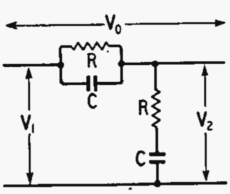


Fig 5 Inverted Wien bridge.

Some early Wien bridge oscillators used this technique. At that time circuit techniques were less developed than they are now, and it was found necessary to use a transformer at the output because of the lack of a common terminal between input and output. It is now possible, however, to use a differential amplifier as shown in Fig. 4(a) to overcome this disadvantage and at the same time provide the extra gain. Another method[3], in which anode and cathode resistors are used as the resistive bridge arms, is shown in Fig. 4(b). The resistive arms of the bridge can be made non-linear, provided that they have slow response (e.g. a thermistor or a lamp) in order to control the gain to that required for a reasonable amplitude of oscillation. Sometimes the non-linearity of the valves is used to limit the amplitude of oscillation[10].

If the Wien half bridge is inverted and the output is taken from across the series capacitor and resistor as shown in Fig. 5, the output voltage V_2 is

$$V_2 = V_1 - V_0$$

so that

$$\frac{V_2}{V_1} = 1 - \frac{V_0}{V_1}$$

The response of the inverted circuit is therefore one minus the response of the original circuit. This inverted circuit response is plotted in Fig. 6. The attenuation is a maximum and the output is in phase with the input when ωCR equals one. The arrangement therefore tends to reject one frequency and it will cause oscillation at this frequency if it is used in a negative feedback loop around an amplifier which has frequency independent positive feedback.

The Wien bridge is occasionally used[11, 12] with dissimilar components as shown in Fig. 7. The object of this is to reduce the attenuation to two times (from three times) at the oscillation frequency. However, this approach reduces the selectivity, as can be seen from the expression for the response of the circuit

$$\frac{V_0}{V_1} = \frac{2j\omega CR}{1 - \omega^2C^2R^2 + 4j\omega CR}$$

which is plotted in Fig. 2 together with the response for the more usual component values.

Two Alternatives

It has been stated that the Wien bridge is not the only circuit giving the vector locus of Fig. 2. Two circuits which give identical results are shown in Fig. 8. These circuits seem much more obvious for application to oscillators than does the Wien bridge, so a search of the literature was made to discover if they had been used. It was found that they were suggested in a short note in 1945 by Dueno[13] and have since been mentioned by Morris[14], but no evidence of their use in oscillators was found. This is surprising, since the only advantage which the Wien arrangement appears to have is an increased input impedance. As with the Wien circuits, the input impedance is constant if a variable capacitor is used. Stray capacitance to earth can easily be taken into account in the circuit of Fig. 8(a), which is therefore to be preferred. While no mention has been found of these circuits being used in

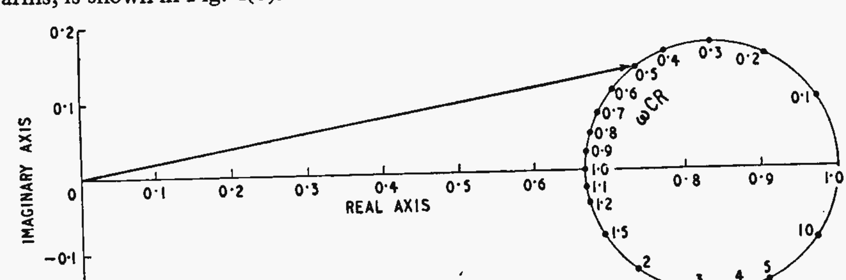


Fig. 6 Response of inverted circuit.

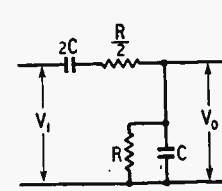


Fig. 7 Wien bridge with dissimilar components.

oscillators, they have been used in a selective amplifier[15].

A variation of these circuits which is used in oscillators[16] is the bridged T shown in Fig. 9. Comparison with Fig. 8(b) shows that the one circuit is the same as the other except that it is inverted. The relationship between the output voltage V_2 in Fig. 9 and the input voltage V_1 can be expressed in terms of voltage V_0 in Fig. 8(b) in the way given above for the inverted Wien bridge, so that

$$\frac{V_2}{V_1}=1-\frac{V_0}{V_1}$$

The vector locus for the circuit of Fig. 9 is therefore a mirror image of that given in Fig. 2, moved over to the right one unit as shown in Fig. 6. The circuit gives a maximum attenuation of 0.66 when ωCR is equal to unity. The rate of change of phase is less than that obtained with the circuits of Fig. 8, though this can be improved by subtraction of a voltage in phase with the input voltage as mentioned in connection with the other circuits. Since the attenuation is a maximum rather than a minimum at the frequency where the output is in phase with the input, the circuit is used in a negative feedback loop around a positive feedback amplifier to produce an oscillator.

If dissimilar values of capacitors and resistors are used, as shown in Fig. 10, the relationship between output and input voltage is

$$\frac{V_0}{V_1}=\frac{j\omega C_1R_1}{1-\omega^2C_1R_1C_2R_2+j\omega(C_1R_1+C_2R_2+C_2R_1)}$$

Now if we make $C_1R_1=C_2R_2=CR$ but make $C_2R_1=KCR$, the relationship becomes

$$\frac{V_0}{V_1}=\frac{j\omega CR}{1-\omega^2C^2R^2+j\omega CR\,(2+K)}$$

This is plotted as a vector locus in Fig. 11 for various values of K. It is seen from Fig. 11 that when K is one, the locus is identical with that given by the Wien bridge, but as K is reduced, the attenuation falls and the selectivity improves. Similar effects can be obtained with the inverted (bridged T) circuits[17, 18] of Fig. 9. To select actual values of the capacitors and resistors for a given frequency, we must have

$$C_1R_1=\frac{1}{6.28f}$$

and $C_2=KC_1$ and $R_2=R_1/K$.

The disadvantage of this arrangement is that as K is reduced so the value of C_2 must be reduced. The stray capacitance across C_2 therefore sets a limit to the value of K which can be used if oscillation is required at high frequencies. A further disadvantage is that the two-gang tuning element, whether it uses resistors or capacitors, must have two dissimilar values which are reasonably accurately ganged.

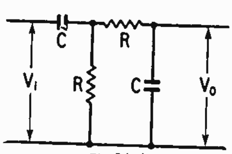


Fig.8(a)

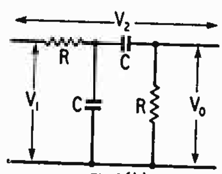


Fig.8(b)

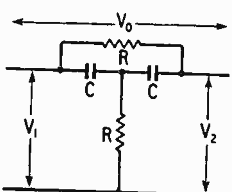


Fig.9

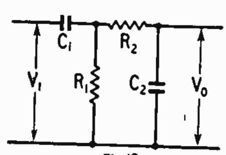


Fig.10

Fig. 8 Alternatives to the Wien bridge.

Fig. 9 Bridged T.

Fig. 10 Circuit with dissimilar components.

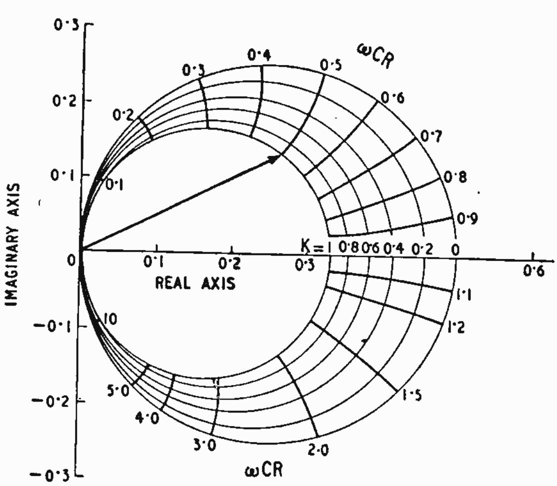


Fig. 11 Effect of variation of K.

Isolating Stages

A value of K equal to zero cannot be obtained with the circuit of Fig. 10, since this would necessitate making R_2 equal to infinity. However, a zero value of K can be obtained by isolating the two halves of the circuit, for example by a cathode follower as shown in Fig. 12. In effect, the circuit is essentially a simple C-R high-pass filter followed by a low-pass filter, both filters having the same cut-off frequency. Once this fact is realized there are clearly many more ways of achieving the same result. For example, Fig. 13 shows how a pentode can be used both to give gain and to isolate the two halves of the circuit. Since the pentode is a constant-current generator, the output voltage is determined by the anode current and the load impedance.

$$V_0=\frac{I_aR}{1+j\omega CR}$$

$$=\frac{g_mV_1j\omega CR}{1-\omega^2C^2R^2+2j\omega CR}$$

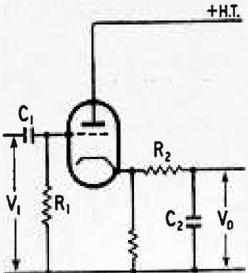
Hence this circuit also gives an effective zero value for K. The advantages of these circuits over Wien bridge circuits are:—

1. The attenuation at the frequency of oscillation is reduced, the output voltage being one half rather than one third of the input voltage.

2. The selectivity is improved, the rate of change of phase with frequency being greater than that of the Wien bridge.

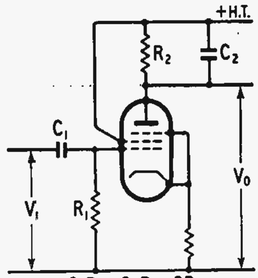
A practical circuit using the arrangement of

(*Continued on page 95*)



$C_1R_1 = C_2R_2 = CR$

Fig. 12



$C_1R_1 = C_2R_2 = CR$

Fig. 13

Fig. 12 Isolated circuit having K=0.

Fig. 13 Pentode isolated circuit.

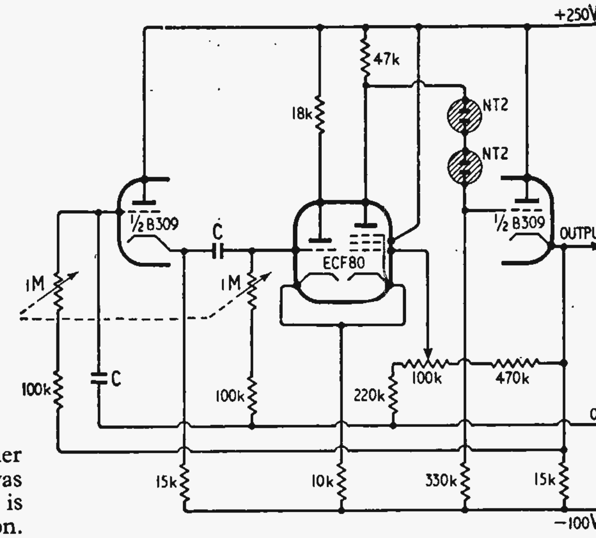


Fig. 14 Practical oscillator circuit.

Fig. 12 in conjunction with the differential amplifier of Fig. 5 is shown in Fig. 14. This circuit was intended for use at quite low frequencies so it is directly coupled except for the high-pass filter section. It is capable of oscillation at several hundred kilocycles per second, however, although no attempt has been made to limit stray capacitance. Since the circuit is required to oscillate at frequencies below the range at which thermistors or lamps can be used in amplitude controls, a manual amplitude control is fitted. This could be replaced in a higher frequency oscillator by non-linear elements.

An ECF80 triode pentode is used as the difference amplifier, with a B309 double triode used as two cathode followers. The output is connected back through the selective circuit in a positive feedback path and through the amplitude control in a negative feedback path. There is thus direct-coupled negative feedback around the amplifier stage and this helps to stabilise the operating bias. Since, at the frequency of oscillation, the positive feedback predominates over the negative feedback, there is a resultant overall positive feedback. Therefore, although the output is taken from a cathode follower the output impedance is several thousand rather than several hundred ohms. An output voltage amplitude of 100 volts peak-to-peak is obtainable with good waveform. The circuit could be used as a selective amplifier by injecting the input voltage to the lower end of the amplitude control chain and adjusting the control to prevent oscillation.

The circuits given have advantages over the usual Wien bridge, although they are inferior to circuits using three variable elements, such as the twin T[1], and to circuits using two selective bridges in cascade[20,21]. The circuits in which the two halves of the filter are isolated are very flexible since the a.c. coupling of the high-pass filter and the d c. coupling of the low-pass filter can be inserted at any suitable points in the oscillator loop, not necessarily adjacent. In a decade oscillator, the source impedance problem[4] is reduced, since, provided both filters are supplied from equal source resistances, the overall effect is simply an attenuation.

It is seen that there are many circuits with only two-gang control capable of giving an identical, or an improved, response compared with the Wien bridge. While most of these have been mentioned in the literature, they seem to have been little used in oscillator circuits. This is surprising when the large number of Wien bridge oscillators which have been described and manufactured is considered.

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Manufacturers' Products

NEW ELECTRONIC EQUIPMENT AND ACCESSORIES

Two Oscillators

IN the Dawe Type 441 a modified Wien bridge oscillator feeds a push-pull amplifier with a cathode-follower output of up to 100mW, constant to within ± 1dB over the frequency range from 5c/s to 600kc/s (covered in 5 decades). The output can be continuously varied by up to 40dB using a bridged-T attenuator to give a constant source impedance of 600Ω. Negative feedback and the use of thermally sensitive resistive elements in the resistive arms of the Wien bridge to stabilize the oscillation amplitude at a level within the linear range of the amplifier together result in a distortion of $\frac{1}{4}$% at all frequencies except below 20c/s where it rises to 0.5% at 5c/s. The hum and noise is less than 0.1% of the maximum output except near the mains supply frequency where it can rise to 0.2%. A small amount of positive feedback round the output stage is used to reduce its impedance nearly to zero (the 600Ω being added to the secondary of the transformer) so that there is negligible reaction of the load on the oscillator. This instrument costs £95.

Another Dawe oscillator with a similar appearance (Type 440) gives an increased output of up to 6W (into 15 or 600Ω) with a total harmonic distortion of less than 0.5% over a narrower frequency range from 40c/s to 15kc/s. Outside this range the distortion rises, but for 3W output does not exceed 3% at the frequency limits (for his oscillator) of 20c/s and 20kc/s. The Type 440 costs £98.

Both these oscillators are manufactured by Dawe Instruments Ltd., of 99, Uxbridge Road, Ealing, London, W.5.

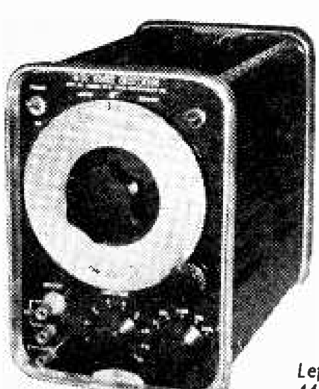
Radio Maintenance Aids

WITH the various chemical cleaning fluids now available there is no reason at all why wavechange switches, or any of the moving parts in a radio set which carry current should persistently remain noisy. A drop of one of these fluids in the right place effects a cure. A new addition is the "Bridisco" switch cleaner, available in two different forms, one in an ordinary tin (standard) the other in a pressurized container described as an "Aerosol" pack. A slight pressure on the top cap of the Aerosol container projects a controlled quantity of the fluid on to the work via a flexible plastic dispensing tube. The standard form costs 4s 1½d and the Aerosol variety 8s 3d. The pressurized pack is said to be very economical.

Other useful items for the professional's or home workshop is a 50-ft card of nylon drive cord for tuning dials (6s) and a tube of radio cement which is said to be acid proof, heat and waterproof and which will join, or repair, metal, glass, plastic, rubber, ceramic and wood among other materials. It costs 2s.

The suppliers are British Distributing Co., 591, Green Lanes, London, N.8.

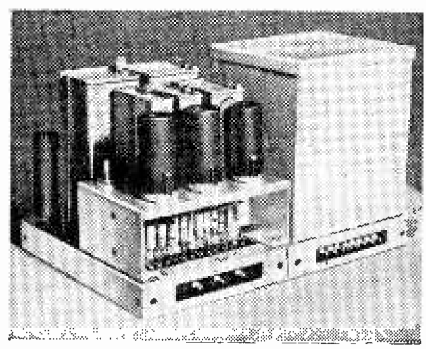
Right:—Bridisco radio switch cleaning fluid in 'Aerosol' (pressure-type) container with flexible dispensing tube.



Left:—Dawe type 441 oscillator.

Stabilized Power Supply

THE "Loma" Type 41 stabilized power supply is intended for use with any industrial electronic equipment requiring a supply voltage of 250V or 300V at 0 to 100mA. It is valve stabilized and employs a high-gain d.c. amplifier and operates from a.c. mains of 200 to 250V, 40 to 60c/s.



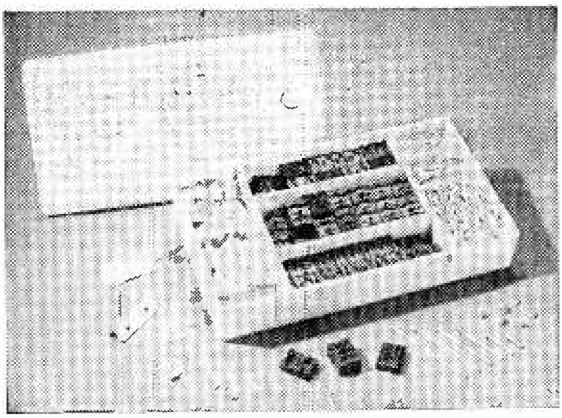
Loma Type 41 stabilized power supply unit (Automa Engineering).

The output voltage is held constant at ± 0.1% over the full working range of load current and for input voltage fluctuations of ± 7%. The output impedance is 0.1Ω and noise and ripple levels are less than 250µV.

The equipment, which consists of two units, can be assembled to give alternative dimensions of 14 × 5 × 6½in or 10 × 7 × 6½in. It is made by Automa Engineering Group, Ltd., Cherry Tree Rise, Buckhurst Hill, Essex, and the price is £31.

Versatile Connector Kit

SHOWN in the illustration is a kit of parts from which a wide variety of the "Varicon" connectors made by N.S.F., Ltd., 31-32, Alfred Place, London, W.C.1, can be assembled with no other tools than a screwdriver. The kit is intended for use of equipment makers and in experimental laboratories requiring at short notice plug and socket connectors of possibly non-standard type. The expression "plug and socket" is not strictly correct in the present case since a feature of the Varicon design



N.S.F. Varicon connector kit.

is that the contacts are flat and fork-shaped, the male and female parts mating with the flat surfaces at right angles.

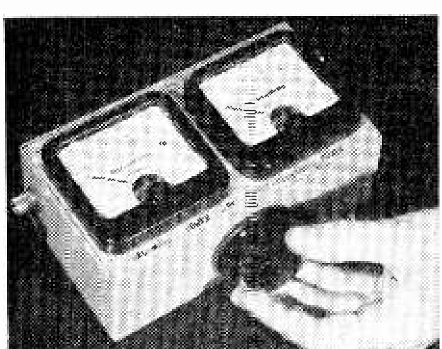
A standard kit contains approximately 460 separate parts and enables connectors with up to 44 contacts to be quickly and easily assembled in a single block.

Magnetic Tape Splicer

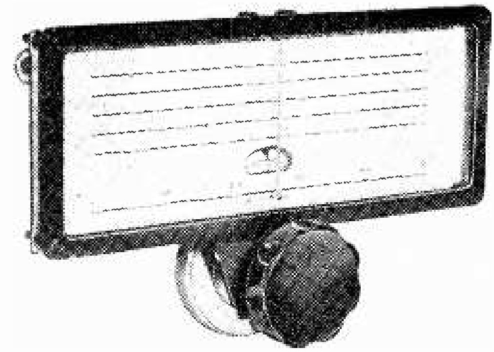
THE photograph shows the "Easysplice" with a length of tape in the position for cutting or splicing. With its coating downwards, the tape is fixed with one edge against a shallow step along the splicer using the spring-loaded clamps at the sides. The tape can be cut by drawing a blade (preferably non-magnetic) along the slot cut through the top of the step and inclined to the tape width. Alternatively, two previously cut lengths of tape can be abutted along their cuts in a similar way, and spliced with adhesive tape. This splicer costs 7s 3d (including postage) and is available from E. Mayrick, 30 Lawrence Road, Ealing, London, W.5.

Coaxial Direction Coupler

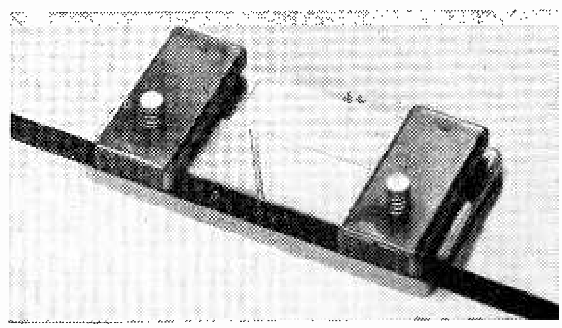
FOR measuring forward- and backward-going powers up to 5W (c.w.) to an accuracy of 2 per cent at any chosen fixed frequency up to 600Mc/s in 52-Ω coaxial lines the directional coupler type A7092 is available from Armstrong Whitworth. The coupling is formed by a single loop which is terminated at its two ends by equal pure resistances. The currents induced in one resistor by the electric and magnetic fields are arranged to add for forward-going power and cancel for backward-going power, these effects being interchanged for the other resistor. Thus the current in one re-



Armstrong Whitworth coaxial directional coupler.



Eddystone geared slow-motion drive unit with overall ratio of 110 to 1.



"Easysplice" magnetic tape splicer.

sistor gives a measure of the forward-going power and that in the other the backward. Since the currents are proportional to the power frequency, the calibration frequency must be specified when ordering. The coupling is, however, broadband, so that the instrument can be used to measure standing wave ratios at other frequencies. The directivity is about 26dB and the coupling coefficient about 30dB. This coupler is manufactured by Sir W. G. Armstrong Whitworth Aircraft, Ltd., Baginton Aerodrome, near Coventry.

Precision Slow-motion Drive

A WELL-MADE slow-motion drive unit (Eddystone Cat. No. 898), intended primarily for precision instrument applications, but eminently suitable also for home-constructed communications receivers, has been introduced by Stratton and Co., Ltd., Eddystone Works, Alvechurch Road, Birmingham, 31.

A pendant pointer $2\frac{1}{4}$in long travels horizontally across six scales 7in in length; five are blank for the instrument calibrations, but the botton one is engraved 0 to 500 in steps of 100. A circular vernier scale marked with 100 divisions makes five complete revolutions for a single traverse of the main pointer, and in conjunction with the 0 to 500 scale provides 500 divisions for precise calibration, or for logging stations if the dial is fitted to a receiver.

The movement is gear-driven assisted by a loaded flywheel, giving a smooth, positive drive with an overall reduction of 110 to 1. The dial measures $9\frac{3}{16}$in × $5\frac{1}{4}$in, weighs approximately 1 lb 4 oz, and is fitted with a Perspex window in a die-cast surround finished in glossy black. The price is £2 18s complete with knole, fixing screws and a drilling template for mounting, and it can be fitted to wood or metal panels of up to approximately $\frac{1}{4}$in thick.

News from the Industry

Preformations, Ltd., has been formed by Plessey to manufacture "Magloy" cast permanent magnets. These are being made in this country under an agreement concluded between Plessey and the Arnold Engineering Co. of Illinois. The new company, of which the directors are A. G. Clark (chairman) and A. E. Underwood, of Plessey, and R. M. Arnold of the American company, is operating from the Plessey Group factories on the Cheney Manor estate at Swindon, Wilts.

Microcell, Ltd., who operate three manufacturing divisions—aircraft engineering, plastics and electronics —at their Camberley and Blackwater (Surrey) works, have been acquired by BTR (British Thermoplastics and Rubber) Industries, Ltd. Their subsidiaries in the glass fibre and polyester resins fields have also been acquired.

Decca Navigator and equipment for its associated long-range system Dectra is being fitted by B.O.A.C. in their North Atlantic Comet 4 fleet. The Ministry of Supply and a number of civil airlines have been conducting tests with Dectra on the North Atlantic routes for the past 18 months. Decca Navigator is already fitted in nearly 5,000 ships and aircraft.

Avo-Taylor Merger.—Avo, Ltd., have acquired the entire share capital of Taylor Electrical Instruments, Ltd., of Slough, Bucks.

Plessey's report for the year ended last June shows a consolidated profit of £1.39M, which is a little below the previous year's figure.

Cosmocord.—It has been pointed out that our note under the title "Pena Aftermath" in the December issue might be construed as inferring that all companies associated with Pena had been put in the hands of a receiver. This is not so, at least as far as Cosmocord is concerned and, as we pointed out last October, the firm is continuing as usual. Several new lines, including stereo pickup cartridges have recently been introduced.

Marconi's are to supply eleven complete VOR installations for this country's civil airways. The internationally agreed frequency range of VOR (v.h.f. omni-directional radio range) is 112-118 Mc/s.

Elremco.—An exhibition of electrical timing and automatic control equipment is being held by Electrical Remote Control Co., at the Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham, 2, on February 10th to 11th. It will be open each day from 10 a.m. to 9 p.m.

International Rectifier Co. (Great Britain) has been formed jointly by the International Rectifier Corp., of Los Angeles, Cal., and the Lancashire Dynamo Holdings, Ltd., for the manufacture of semiconductors in the U.K. The principal products to be produced at a factory being built in the Home Counties are silicon diodes and silicon power rectifiers. Until the new factory starts production towards the end of the year a temporary assembly line for semi-manufactured products has been set up.

E.M.I.-Cossor Electronics is the new name of Cossor (Canada) in which Electric and Musical Industries has acquired a controlling interest. Henry Chisholm, joint managing director of A. C. Cossor, continues as chairman of the Canadian company and Clifford Metcalfe, a managing director of E.M.I., becomes president.

E.M.I. Electronics have developed, in conjunction with the U.K. Atomic Energy Authority, a transistor data recording and analysing system to assist in handling the enormous quantity of statistical data from nuclear experiments at the research establishment at Harwell. The system is made up of a number of self-contained recording units which, situated near the experimental rig, take the measured quantities and convert them into binary coded digital form. The data is recorded on 16 parallel channels on 1-in magnetic tape and this is fed into a central high-speed analyser.

Marconi Marine.—Among new vessels recently fitted by Marconi's with radio navigational aids and communications gear are the Union-Castle's 28,500-ton liner *Pendennis Castle*, the 7,700-ton cargo liner *City of Hereford*, and the Grimsby trawler *Yesso*.

Gillone Electric, Ltd., of Camberley, Surrey, are now fully recovered from their recent fire and in full-scale production again. Employing some three hundred people, the company manufactures 90° and 110° deflector coils, line transformers and a variety of coils.

Radiospares, Ltd., of 4-8, Maple Street, London, W.1, announce the appointment of Gordon Johnson as sales manager.

British Sarozal, Ltd., have moved from 1-3, Marylebone Passage, Margaret Street, London, W.1, to 22, Berners Street, W.1, with workshops and stores at 36, Berners Mews. A showroom will also be opened in the near future. The telephone number remains unchanged (Langham 9351).

Painton & Co., Ltd., of Kingsthorpe, Northampton, have recently concluded an agreement with Bourns Laboratories Inc. of Riverside, Cal., whereby they have the exclusive European and Australian manufacturing and distribution rights for the range of "Trimpot" potentiometers.

Saba tape-recorders, which are manufactured in Western Germany, are being handled in this country by Henri Selmer & Co., of 114-116, Charing Cross Road, London, W.C.2, who have been appointed sole concessionaires in the U.K.

Texas Instruments, Ltd., of Bedford, the first European subsidiary of the American transistor manufacturers of the same name, announce the appointment of Cecil Dotson, of Dallas, Texas, as chairman of the board. The company is planning the erection of a new factory at Hoo Farm, Bedford.

Steatite Insulations, Ltd., have moved from Edgbaston to 31, George Street, Lozells, Birmingham, 19. (Tel.: Northern 8357/8.)

EXPORTS

Norway's telecommunications network is being extended to the northern areas where only a limited telephone service at present exists. Marconi's are providing four v.h.f. multi-channel terminals and two repeaters for the extension which covers a distance of about 200 miles.

Domestic sound and television equipment is included in the display of some 400 British products being arranged in the Museum of Decorative Art in Copenhagen by the Council of Industrial Design and the British Import Union of Denmark for May 2nd to 17th.

Instruments.—Displays of their equipment in Budapest and Copenhagen during February are being arranged by Dawe Instruments. Overseas exhibitions in which they plan to participate include the Leipzig Fair (March) and possibly another in Moscow in March with other S.I.M.A. members.

Ethiopia.—A. & N. Knadjian, P.O. Box 1448, Addis Ababa, would like to import U.K. manufactured portable transistor sets. They should cover the short-wave bands, especially those of 11 and 13 metres.

Ceylon.—Queen's Radio and Television Corporation, of 861, Alutmawatte Road, Colombo 15, are interested in representing a U.K. manufacturer of components, particularly resistors, capacitors, i.f. transformers and volume controls.

FEBRUARY MEETINGS

Tickets are required for some meetings; readers are advised therefore to communicate with the secretary of the society concerned

LONDON

4th. Brit. I.R.E.—Inaugural meeting of the Computer Group at 6.30 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

4th. British Kinematograph Society.—"Problems of Telecine" by R. Whatley (B.B.C.) at 7.30 at the Royal Society of Arts, John Adam Street, W.C.2.

6th. I.E.E. Medical Electronics Group.—Discussion on "Problems of storing transient phenomena for subsequent analysis" opened by Dr. P. Bauwens and P. Styles (St. Thomas's Hospital) at 6.0 at Savoy Place, W.C.2.

6th. Television Society.—"Master control room techniques" by B. Marsden (Associated Television) at 7.0 at the Cinematograph Exhibitors' Association, 164 Shaftesbury Avenue, W.C.2.

9th. I.E.E.—Discussion on "Dissemination and assimilation of technical literature—a growing problem" opened by J. K. Webb, chairman of the Measurement and Control Section at 5.30 at Savoy Place, W.C.2.

13th. Brit. I.R.E. Medical Electronics Group.—"Some instrumentation problems in medical electronics with particular reference to electro-myography" by P. Styles at 6.30 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

13th. Radar and Electronics Association, Student Section.—"Trends and developments in marine radar" (by a member of Marconi's) at 7.0 at the Norwood Technical College, S.E.27.

18th. I.E.E.—"Ultrasonic iconoscopes" by C. N. Smyth and J. Sayers at 5.30 at Savoy Place, W.C.2.

20th. I.E.E.—"The sources and correction of errors in data transmission" by V. J. Terry and E. P. G. Wright at 5.30 at Savoy Place, W.C.2.

20th. B.S.R.A.—"The design of an electronic organ for the home" by G. W. Barnes at 7.15 at the Royal Society of Arts, John Adam Street, W.C.2.

23rd. I.E.E.—"A simple investigation of the cross-modulation distortion arising from the pulling effect in a frequency-modulated klystron" by D. Gjessing; "Theory and behaviour of helix structures for a high-power pulsed travelling-wave tube" by G. W. Buckley and J. Gunson; "A multi-cavity klystron with double-tuned output circuit" by H. J. Curnow and L. E. S. Mathias; and "A method for the measurement of very-high Q-factors of electromagnetic resonators" by F. H. James at 5.30 at Savoy Place, W.C.2.

25th. Brit. I.R.E.—"Patents and the radio engineer" by E. D. Swann at 6.30 at the London School of Hygiene and Tropical Medicine, Keppel St., W.C.1.

25th. British Kinematograph Society.—"Television picture reproduction" by T. C. Macnamara and D. Styles (Associated Television) at 7.30 at the R.S.A., John Adam Street, W.C.2.

26th. Physical Society.—Discussion on "Of what use is acoustics to the musician?" opened by Professor E. G. Richardson at The Royal Academy of Music, Marylebone Road, N.W.1.

26th. Television Society.—"A colour signal encoder for laboratory use" by S. H. Cohen and P. C. Kidd (Murphy) at 7.0 at the Cinematograph Exhibitors' Association, Shaftesbury Avenue, W.C.2.

BRISTOL

10th. Television Society.—"Modern communications, methods and applications" by J. Sloan (B.C.C.) at 7.30 at the Hawthornes Hotel, Clifton.

CHELTENHAM

27th. Brit.I.R.E.—"Micro-miniaturization" by G. W. A. Dummer at 7.0 at North Gloucestershire Technical College.

EDINBURGH

20th. Brit.I.R.E.—"Tru motion radar" by J. H. Beattie at 7.0 at the Department of Natural Philosophy, The University, Drummond Street.

GLASGOW

19th. Brit.I.R.E.—"True motion radar" by J. H. Beattie at the Institution of Engineers and Shipbuilders, 39 Elmbank Crescent.

LEEDS

3rd. I.E.E.—"Survey of performance criteria and design considerations in high-quality monitoring loudspeakers" by D. E. L. Shorter at 6.30 at the C.E.G.B. Offices.

10th. I.E.E.—Discussion on "Co-operation between college and industry on industrial training schemes" at 6.30 at the C.E.G.B. Offices.

LIVERPOOL

20th. Brit.I.R.E.—"Electronic welding controls" by C. R. Bates at 7.0 at the University Club.

26th. I.E.E.—Faraday Lecture on "Automation" by Dr. H. A. Thomas at 6.45 at the Philharmonic Hall.

MANCHESTER

4th. Brit.I.R.E.—"Recent astronomical research using radio waves" by Dr. H. P. Palmer at 6.30 at the Reynolds Hall, College of Science and Technology, Sackville Street.

27th. Institution of Electronics.—"Electronics in industry—including computer applications" by R. S. Evans (Ferranti) at 7.0 in the Reynolds Hall, College of Science and Technology.

NOTTINGHAM

19th. Society of Instrument Technology.—"Data collection and processing" by a member of Solartron Industrial Controls at 7.0 at the Technical College, Shakespeare Street.

NEWCASTLE

11th. Brit. I.R.E. — "Stereophonic sound from records" by P. B. Cooper at 6.0 at the Institution of Mining, Neville Hall, Westgate Road.

RUGBY

25th. I.E.E.—"Storage and manipulation of information in the brain" by Dr. R. L. Beurle at 6.30 at the College of Technology and Arts.

SHEFFIELD

4th. Society of Instrument Technology.—"The future of solid state electronics in instruments" by H. Kemhadjian at 7.0 at the University.

TREFOREST

11th. Brit. I.R.E.—"Industrial television" by E. A. Naef at 6.30 at Glamorgan College of Technology.

WOLVERHAMPTON

11th. Brit. I.R.E.—"Some aspects of the control of nuclear reactors" by L. W. J. Newman at 7.15 at the Wolverhampton and Staffordshire College of Technology, Wulfruna Street.

RANDOM RADIATIONS

By "DIALLIST"

Satellites as Relays

THE American satellite, Atlas, which, as I write, is circling this Earth of ours, has proved that the idea of telecommunication via a satellite put forward by R. J. Hitchcock, of Cable & Wireless, and mentioned in "Random Radiations" just over a year ago, is a practical possibility. It was, if you remember, that messages for a distant country should be fed into a satellite when it was within range, recorded and then retransmitted as it passed over the place for which they were intended. This has been done with considerable success with Atlas. As many as seven sets of teleprinter code messages have been sent to it simultaneously and played back with excellent results when the satellite was ordered to do so. Speech-modulated signals have also been sent and received with success. At the moment there are naturally not a few snags, such as the cost of a satellite and of its launching as well as the comparatively short time that it is likely to remain in action. But it's a beginning and one can't have much doubt that these difficulties will be ironed out in time.

Easier Viewing

AS you may recall, I've more than once recommended that the height of television receivers above the floor should be made adjustable so as to make for the most comfortable viewing conditions. So far, I haven't come across a domestic set designed on these lines, but I'm very much taken with a new idea for schools receivers due to Clarke & Smith, of Wallington, Surrey. The receiver is fitted into a mobile tubular steel cradle in which it can be raised or lowered to two viewing positions. The centre of the screen can thus be set at 3ft or 5ft from the floor. Now that the general circuitry of television receivers has become more or less standardized one hopes that manufacturers of domestic sets will give more thought to two very important things: increasing the viewers comfort and making the serviceman's job easier when he has to attend to the "works." Murphys made a move in the right direction when they produced the model which is balanced on trunnions fitted to vertical supports at the side of the stand so that the screen can be tilted to the angle best suited to the viewer.

Give 'em Points Enough!

MUCH as I had wanted to attend the I.E.E. symposium on the Provision of Adequate Electrical Installations in Buildings, I couldn't manage it. The ring main system of wiring was preferred by most of those who took part and I couldn't agree more. A point—and it's one of great importance—was made by C. A. Belcher about the number of sockets provided in the average house. There are nearly always too few when the wiring is done, and one of the certainties of this life is that very many people will add points, often doing the job themselves and unconsciously adopting safety-last methods! Multiple adaptors are often seen in wall sockets—and if the load proves too much for a 5-amp fuse, that's readily cured (!) by fitting one of 10-amp wire instead. But the thing that really gives me the creeps is to see a room festooned with long trailing lengths of cheap flex. I know one house where the TV set receives its mains supply *via* a good 20 feet of flex. Flex is fine stuff for its proper purpose, but it's not intended to be trodden on (or tripped over!) and the do-it-yourself fixer-up of electrical extensions too often believes that its life is pretty well unlimited.

Servicemen's Pay

OCCASIONALLY I hear of well-qualified young radio technicians who are receiving less than the standard rates of pay recommended by the Radio and Television Retailers' Association. This is a bad business. Actually, the recommended basic rate for one who has completed his apprenticeship, or has done five years' servicing after reaching the age of 21 is 10 gns a week. The minimum rate for holders of the Radio Trades Examination Board's final certificate in radio servicing is £11 10s, and for those who have the Board's final television servicing certificate it is £12 10s. The recommended minimum weekly rates for apprentices rise from £2 5s at 15 to £6 7s 6d at 20.

Comprehensive

A COPY of the guarantee which his firm has been giving for some years on all domestic sound and vision receivers sold by them has been sent to me by a Radio Rentals manager. It's the sort of guarantee that I'd like to see in more general use, for it completely covers the buyer for two years from the date of purchase. It embraces the c.r.t., all valves and all components. And there's more to it than that, for it undertakes that free servicing and maintenance shall be provided during the whole of that period. These things can't, of course, be really free—the purchase price must be so adjusted that the customer does the paying—otherwise there wouldn't be any profits. But I feel that people would rather pay a bit more for new sets if it meant that they knew exactly where they stood in the matter of running costs for two whole years—these can be no more than the price of a receiving licence and a few shillings for electricity from the mains. And there can't be any nasty shocks in the form of large repair bills. Another good thing about so comprehensive a guarantee is that it means that the maker who gives it must be pretty confident about the reliability of his wares, if he's not going to loose money.

CLUB NEWS

Barnet.—At the meeting of the Barnet and District Radio Club on February 24th G. G. Gibbs (G3AAZ) will deal with the subject of transmitter construction. Lecture meetings are held on the last Tuesday of each month at 8.0 at The Red Lion Hotel, High Barnet.

Bexleyheath.—At the February meetings of the North Kent Radio Society lecture demonstrations on electrometry in industry will be given by R. E. Gemmell on the 12th; and on tape recording for the amateur by R. Mallinson (G3GOG) on the 26th. Meetings are held at 8.0 at the Congregational Hall, Clock Tower.

Birmingham.—"The Human Ear" is the title of the talk being given by C. Naylor Strong to the Slade Radio Society at 7.45 on February 13th at the Church House, High Street, Erdington.

Bradford.—Dr. G. N. Patchett will speak on colour television at a meeting on February 10th to which various clubs in the area have been invited. The meeting will be held at 7.30 at the Bradford Institute of Technology, where Dr. Patchett is head of the Electrical Engineering Department.

Halifax.—A talk entitled "DX expeditions" will be given by M. G. Whittaker (G3IGW) at the February 3rd meeting of the Halifax & District Amateur Radio Society at the Sportsman Inn, Bradshaw.

Manchester.—The design and construction of a 20-watt transistor audio amplifier will be considered by the meeting of the South Manchester Radio Club on February 6th. The Club meets every Friday at 7.30 at Ladybarn House, 17 Mauldeth Road, with a lecture meeting once a month.

South Kensington. — A lecture demonstration on high-fidelity and stereophonic techniques will be given by Tannoy at the meeting of the Civil Service Radio Society on February 9th. The meeting will be held at 6.0 in the Lecture Hall of the Science Museum (entrance in Imperial Institute Road).

6519

UNBIASED

By FREE GRID

"*1066 and all that*"

EVERY English schoolboy knows that William the Conqueror invaded England by landing at Pevensey on 28th September, 1066, but did not join battle with Harold at Hastings until over a fortnight later, on 14th October. At least, in my young days every schoolboy knew it—or took the consequences—and even many schoolgirls knew it also.

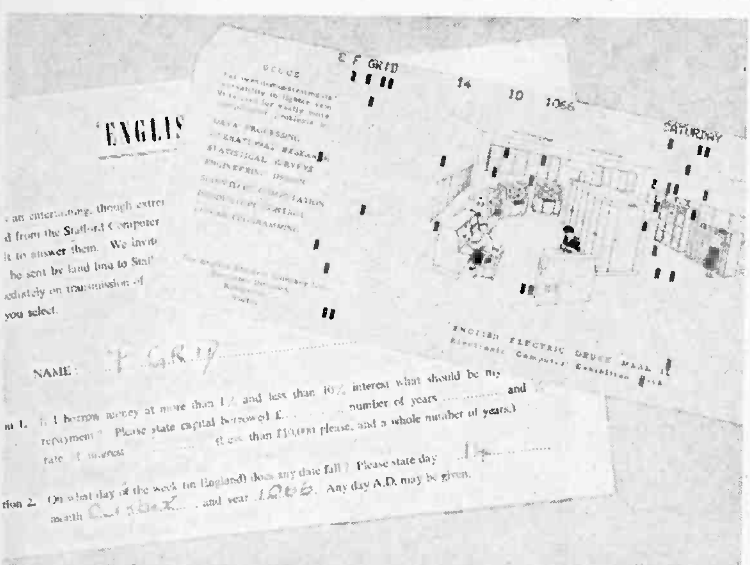
However, one thing we didn't know was the day of the week on which the battle of Hastings was fought. I have frequently relieved the tedium of a long train journey by working out the days of the week on which important historical dates occurred as I have found it so much more entertaining than cross-word puzzles, and it at least provides me with some useful pieces of information.

I started this habit long ago when I happened to be standing on the beach at Deal where Julius Caesar landed on 25th August in the year 55 B.C. On that occasion I got into a hopeless muddle by forgetting that the Julian Calendar did not come into existence until several years later, and I was well able to sympathize with the popular song writer who, when Eastern Europe altered its calendar in 1923, expressed his own—and other people's—bewilderment and confusion by giving us the nonsense song "When it's night-time in Italy, it's Wednesday over here."

You can imagine my delight, therefore, when happening to pass the English Electric Company's stand at the recent Electronic Computer Exhibition at Olympia, I saw a notice inviting me to ask their "Deuce" digital computer on what day of the week any particular date fell.

Unfortunately, however, "Deuce" apparently found the pre-Julian Calendar as puzzling as I did, as it restricted my queries to A.D. years. I am, therefore, still ignorant of the day of the week when Caesar landed, but I had no difficulty in checking that William fought Harold at Hastings on a Saturday. My question form and the machine's punched-out reply card is reproduced herewith. I also checked on several other historical dates.

Apart from this "A.D. only" restriction, "Deuce" limited its replies to dates "in England." This thoroughly aroused the ire of a Scotsman who was sitting next to me in the audience, and he remarked rather bitterly that little better could be expected of a company which called itself the *English* Electric Co. He added that obviously they did not wish to draw attention to the fact that England had seen the error of its ways and adopted the Scottish Calendar in 1752 despite the battle of Culloden only a few years earlier. That reminds me that I ought to have asked "Deuce" on what day of the week September 5th, 1752, fell in England. If this catches the eye of one of "Deuce's" progenitors perhaps he will tell me what reply I should have got.



Lo-Fi Tapes

I AM glad to see that more tape recorders are coming on the market with a speed of $7\frac{1}{2}$ in/sec. Since all recorded tapes on sale are made at this speed they obviously cannot be used on the average single speed machine which caters for only $3\frac{3}{4}$ in/sec, or in certain makes $1\frac{7}{8}$ in/sec. By far the greater number of machines sold are single-speed ones and this obviously shows that most people buy recorders solely for the purpose of recording their own voices or those of their friends and not for playing commercial recorded tapes.

I cannot help feeling that there would be a very big market for commercial tapes recorded at $3\frac{3}{4}$ in/sec. The frequency response at this speed goes up to 10,000 c/s in the better machines, which is more than good enough for the ordinary "pop" record. I do hope, therefore, that manufacturers will soon let us have "$3\frac{3}{4}$" recorded tapes.

Mc/s and Mc/ms

WE abandoned wavelengths in favour of frequencies partly because, with the ever lessening length of waves, we began to get involved with decimal points, and we were reluctant to measure our waves in Angstrom units as this would have involved us in very big and unwieldy numbers.

However, frequencies are increasing so rapidly that we are once more getting involved with big numbers. Use of the Greek prefix "mega" has helped quite a bit but further progress into the realm of higher and higher frequencies will necessitate that something further be done. I wonder whether it would not be a good thing to start dividing the seconds instead of continuing to multiply the frequency so that 1000 Mc/s became 1Mc/ms or, in other words, one megacycle per millisecond. Any objections?

Morse Legibility

ONE of the things which attracted my attention at the Radio Hobbies Exhibition in November was the comparatively slow-speed morse being churned out by the telegraphists at the R.N.R. exhibit. It did not seem to me to be much above 20 w.p.m. and a Petty Officer to whom I spoke said that actually it was 22 w.p.m. He said this enabled consistent legibility to be kept up over a long period when not using a typewriter for taking down.

If you want to try it yourself you can do so without learning morse. All you have to do is to think of some well-known words like those of the National Anthem and see how quickly you can write them down. If you do so at 30 w.p.m. you won't be able to read much of your handwriting. Taking down at 30 w.m.p. on a typewriter is not, of course difficult. The world's champion wireless operator attained a speed of 73 w.p.m., I believe.

[The speed required for the P.M.G.'s 1st Class Certificate is 25 w.p.m. The average number of letters in a word is 5 and the duration of the test 5 minutes.—ED.]