NOVEMBER 1960
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Wireless World

Electronic Air Traffic Control

FEW more challenging tasks have been presented to electronics than that of freeing the bottleneck which threatens to restrict further expansion of air transport, namely, the saturation of airways and existing traffic control procedures by the ever-increasing numbers and speeds of jet and turbo-prop aircraft now entering service.

Expansion of air transport to its present volume has depended as much on radio and electronics as on aircraft design. Navigational aids, and instrument approach systems, have gone far in solving the problems of night and bad-weather flying. Today the world's airlines run traffic schedules comparable in complexity with those of the railways, but with at least three significant differences—the time scale, the fact that movement is in three instead of two dimensions and that, unlike trains or road vehicles, aircraft awaiting the signal to land consume large quantities of fuel.

The existing system of traffic control is founded on flight progress strips which are based on pilots' reports of positions and estimated times of arrival at successive reporting points. These are displayed on the controller's progress board and are continuously "up-dated" by him. From an inspection of these data he anticipates possible future "conflictions" and issues flight instructions (clearances) to maintain an orderly flow of traffic with safe spacing based on a knowledge of possible errors of navigation and of time delays in communication. Under present conditions the "error volume" per aircraft is large and is the reason why, particularly on the North Atlantic routes, at certain times of the day, no more aircraft can at present be put into the airspace. More people want to fly and airlines have already ordered more high-speed jets, but the time is not far distant, if it has not arrived already, when air traffic control will have to say that it cannot accept any further extension of schedules. This is a world problem, for an airport must accept foreign aircraft as well as dispatch its own traffic at times which will be acceptable at other centres.

The solution of the problem rests on greater precision in navigation and on greater speed of communication, both of which can be provided by electronic methods. Excellent surveys of the possibilities and of present achievements have been given recently.* These envisage in the first instance the automatic reporting, by facsimile methods or in digital codes, of navigational information from hyperbolic or Doppler flight logs with transmission times of the order of milliseconds and the automatic preparation of accurate and up-to-date progress strips for the controller. Subsequently there is the possibility of processing this data in three-dimensional Cartesian co-ordinates, of computing the future positions of aircraft and giving automatic warning of conflictions. There is the alternative possibility of deriving flight data from radar displays, of presenting the controller with a synthesized display giving only essential information which might include, instead of the familiar phosphor persistence "tails," vectors pointing in the opposite direction and showing the future positions of all aircraft in the area. Large-scale projects to test these and other possible methods, including not only the detection but the resolution of conflicts, are already in progress by the Federal Aviation Agency at Indianapolis, by N.V. Hollandse Signaalapparaten at Schiphol in Holland and by the Ministry of Aviation at the Oceanic Control Centre at Prestwick.

The Guild of Air Traffic Control Officers at their Third Convention last month in Bournemouth discussed all these projects and welcomed the promised aids in the knowledge that while they could relieve them of tedious routine "book-keeping" they would not in the foreseeable future compete with the experience and flexibility of the human controller in dealing with an emergency. These aids could take out of his hands the monitoring of normal flights and allow him to give his undivided attention to the small percentage of situations calling for the exercise of his store of knowledge and experience—as yet unrivalled by the capacity of any computer.

Considerable sums of money are being spent on the development and testing of electronic navigational and control systems of different kinds, but it will be some time before technical assessments can be completed and operational procedures modified to admit these extensions of human faculties. But it is to be hoped that decisions will not become bogged down in too many committees, and that those elements of a future co-ordinated world system which have for their object the simplification and reduction of the information presented to the controller, may be quickly adopted and, where desirable, standardized.

* See, for example, papers in the "Symposium on Data Handling and Display Systems for Air Traffic Control." Vol. 107, Part B, *Proc. I.E.E.*, and "Air Traffic Control" by C. D. Colchester. (Marconi's W/T Co. Ltd. Price 17s 6d.)

Microwave Aerial Measurements

AUTOMATIC APPARATUS FOR PLOTTING PHASE AND AMPLITUDE DISTRIBUTION

By C. M. CADE*, M.Brit.I.R.E., M.A.I.E.E., S.M.I.R.E., and A. T. ELLIOTT*, A.M.Brit.I.R.E.

ONE of the most frustrating factors in the design of any aerial system is the time involved in the measurement of polar diagrams, where on external sites the vagaries of the weather can cause considerable delays. Measurement of the amplitude and phase distribution of the near field radiation pattern is a convenient method of obtaining experimental data on the performance of the aerial, and has the great advantage that these tests can be carried out in the laboratory. Having obtained the desired characteristics, the polar diagram measurements need only be carried out as a final check. This method was used for the development of the X-band slotted array shown in Fig. 1.

Fig. 1. Five-foot slotted X-band array for a marine radar equipment.

Most systems in use for phase distribution measurements are based upon similar principles. The aerial under test is energized from a low-power source and a sample of the radiated power is picked up on a small receiving aerial and then compared with a reference signal coming directly from the same source. If the receiving aerial is moved over the aperture, the two signals will either add or cancel, and a pattern similar to Fig. 2 can be produced. Each null point represents a phase change of $\pi/2$ radians. If a phase shifter is then provided for varying the phase of one signal relative to the other, so that a maximum signal is always maintained, then the phase shifter will indicate directly the phase of the radiation.

However, these simple systems are subject to many inaccuracies. The sampling aerial has to convey its signal either by coaxial cable, flexible waveguide or rigid waveguide incorporating several rotating joints. These moving parts can all cause random phase variations. Other errors can be introduced due to the laborious nature of the measurements, and also by the fact that the pick-up aerial is of large physical size and introduces considerable distortion into the field under measurement.

In the automatic phase plotter developed by the authors, instead of a sampling aerial being used, an isolated half-wave dipole is mounted in the field of the aerial under test and reflects a part of the radiated signal back into the aerial. A general view of the apparatus is given in Fig. 3. The dipole aerial is of such small dimensions that it introduces negligible distortion into the micro-wave field. This is the method first described by Cullen and Parr.† By the use of suitable directional feeds, the reflected sample is compared in phase with the source, and the resultant signal is detected on a crystal. In order to discriminate between reflections from the dipole and unwanted spurious reflections, the dipole is arranged to rotate so that the required signal is modulated at twice the dipole rotational frequency, and can therefore easily be separated from spurious reflected signals. The required separation is obtained by feeding the signal into a high-Q selective amplifier tuned to the modulation frequency. This arrangement has the further advantage that suitable selection of dipole rotational speed and selective amplifier frequency results in the rejection of noise and mains hum interference.

In order to maintain a constant-phase signal at the crystal the height of the rotating dipole above the aerial undergoing test is automatically adjusted by a velodyne servo motor (Fig. 4). The aerial to be tested is energized by a klystron and is mounted beside a railway track. A trolley moves along the track, carrying the rotating dipole over the aerial aperture, and the dipole movement is plotted by an

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*Radar Research Dept., Kelvin & Hughes Ltd.

†Cullen, A. L. and Parr, J. C. *Proc. I.E.E.* 102, Part B. No. 6, November 1955. "A New Perturbation Method for Measuring Microwave Fields in Free Space."

Fig. 2. Oscilloscope recording of phase and amplitude response of five-foot array.

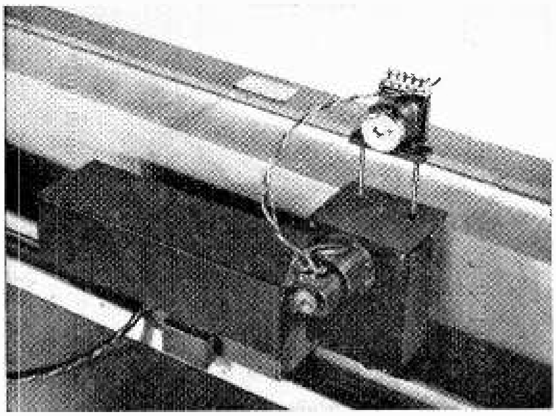


Fig. 3. General view of an aerial under test. The railway, velodyne servo motor and dipole motor can be seen. The small dipole is at the end of the insulated motor spindle.

automatic pen recorder (Fig. 5). From the diagram obtained and a knowledge of the wavelength in use, the phase-angle of the aerial can be readily calculated.

The Complete System.—The block diagram is shown in Fig. 6. The dipole motor is a 3-phase, 50-c/s, 3,000-r.p.m. type. Operating it from a 20-watt audio amplifier driven by a 63-c/s oscillator produces a speed of 3,780 r.p.m. and a signal frequency of 126 c/s, conveniently spaced between the second and third harmonics of the mains.

The reflected signal from the dipole is passed through the directional coupler to a crystal mixer, where a relatively large-amplitude sample of a klystron transmission is mixed with it, the sample being obtained by reflection from a mismatching screw in one arm of a directive feed. The crystal mixer output is taken to a pre-amplifier, thence to the selective amplifier.

As the trolley moves along the test aerial, the rotating dipole traces a path of the contour of constant phase, the dipole height being adjusted by a screw jack system driven by a velodyne. The output from the selective amplifier is fed into a phase-sensitive detector whose reference input is a 126-c/s signal obtained by frequency-doubling of the 63-c/s dipole motor supply. The phase-sensitive detector circuit is shown in Fig. 7. The selective amplifier output changes in phase by 180° when

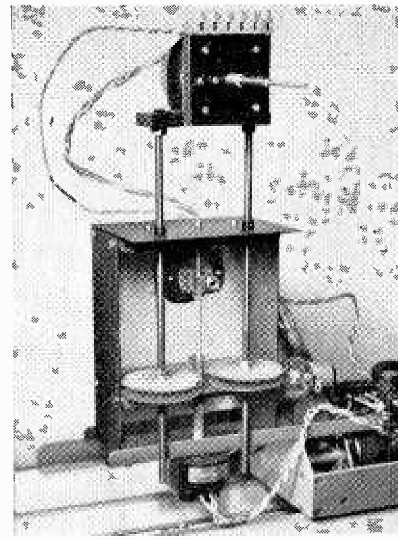


Fig. 4. Trolley, with rotating dipcle and motor mounted on the threaded jacking rods. Note also the velodyne worm drive and, below, the "M" transmitter motor. The lamp is a ballast resistance in series with the velodyne armature.

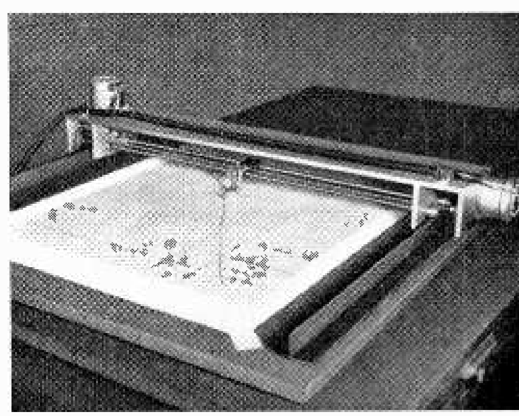


Fig. 5. Automatic pen recorder. The carriage drive motor is on the left, and the "M" receiver motor on the extreme right.

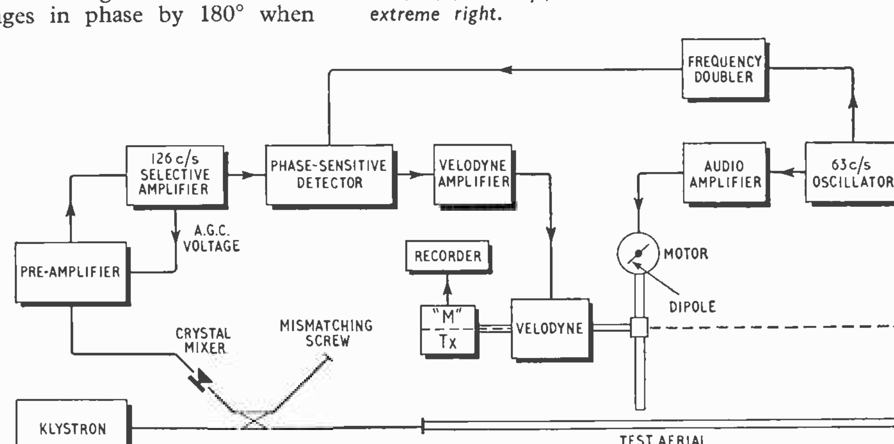


Fig. 6. Block diagram of automatic phase plotter.

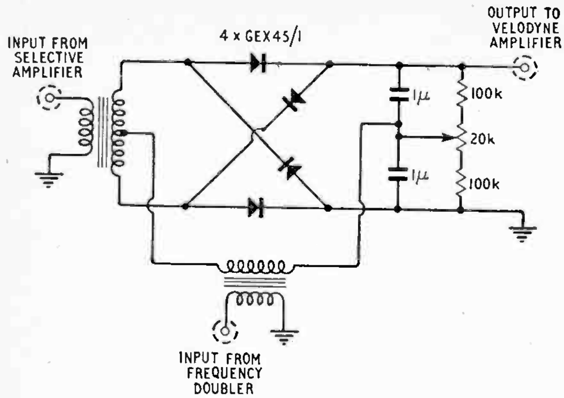


Fig. 7. Phase-sensitive detector.

passing through a null point, and hence the phase-sensitive detector operates as a discriminator, controlling the velodyne amplifier. The dipole height is automatically adjusted and zero discriminator output maintained. Since the power distribution of a linear array varies by some 30 dB along the length, it is important to ensure that the system has an adequate dynamic range, and suitable a.g.c. circuits are essential. It is found in practice that a complex amplified automatic gain control system is required, for even small variations in signal strength will affect the loop gain and response of the servo system.

Selective Amplifier Requirements.—To obtain adequate rejection of mains hum and its harmonics, it is necessary for the selective amplifier response to be some 30 dB down at 100 c/s and 150 c/s. A parallel-T feedback amplifier is suitable, the bandwidth being 2 c/s. The circuit diagram is shown in Fig. 8. With this narrow bandwidth, the amplifier build-up time is appreciable, and limits the velocity of the trolley carrying the rotating dipole. The build-up time of a frequency selective circuit is given by:—

$$T = \frac{1}{\Delta f \pi} \text{ seconds} \qquad (1)$$

where Δf is the bandwidth. The build-up time of the amplifier employed is 160 milliseconds.

It may be shown that the trolley velocity is limited to:—

$$V \not> \frac{l}{2\phi T \times 100} \text{ cm/second} \qquad (2)$$

where l = test aerial length.
ϕ = total phase change along aerial.

In the case of the slotted array under test, these parameters were

l = 150 cm.
$\phi = 8\pi$ radians (at a frequency of 9,500 Mc/s).

Inserting these figures in the formula gives a maximum velocity of approximately 0.2 cm/second.

Mechanical Tolerances.—The height of the rotating dipole must be known accurately, since any error in the recording of its height produces an inaccuracy in the phase plot.

If Δh is a random change in height of the dipole, then the change in phase of the signal will be

$$\phi_h = 2\pi \times \frac{2\Delta h}{\lambda_o} \text{ radians} \qquad (3)$$

where λ_o = free space wavelength.

This formula can be re-written to obtain the error for each thousandth of an inch variation in the dipole height, in which case:

$$\phi_h = \frac{1.83}{\lambda_o} \text{ degrees/thou.} \qquad (4)$$

Thus, $\phi_h \simeq 0.6$ degrees/thou. for $\lambda_o = 3.2$ cm. If we assume that the closest economically practicable tolerance for a fifteen-foot long railway is $\pm 1/64$ inch,

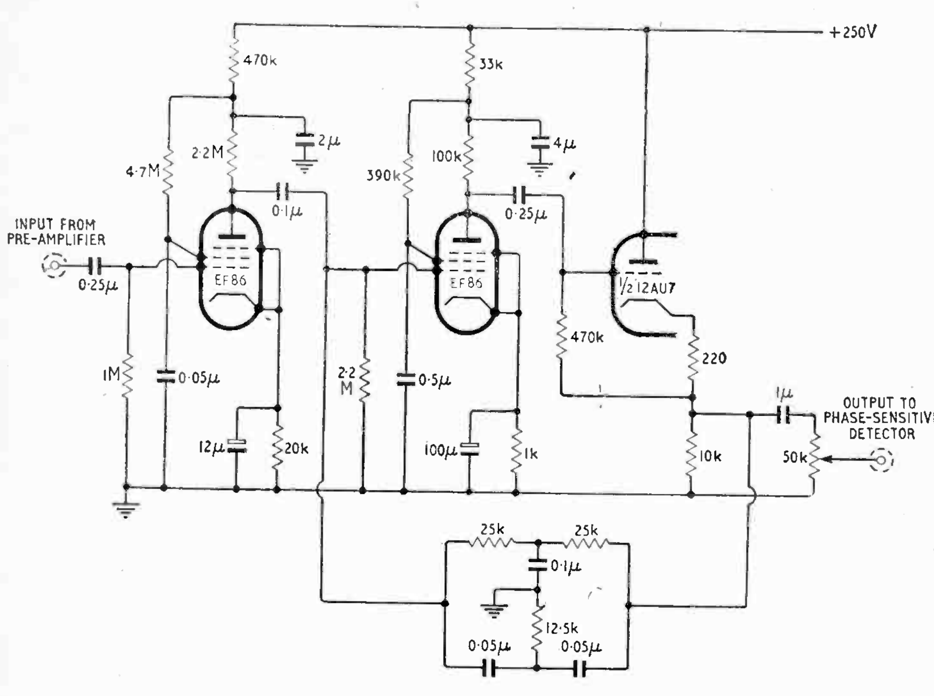


Fig. 8. 126-c/s selective amplifier.

the phase error in the system will be approximately ±10 degrees.

Klystron Ripple.—Consideration must be given to the effect of power-pack ripple on the klystron performance. If the ripple is excessive the signal may be swamped with hum. Also, the phase of the klystron oscillation could change sufficiently during the time taken by a signal to travel to the end of the aerial and return, and an error would occur in the recorded phase angle.

Assuming the maximum test aerial length to be fifteen feet, then the return path from the aerial to the crystal mixer would be some 10 metres. If the velocity of propagation in the waveguide is 200×10^6 metres/second, then the delay time becomes 1/20 μsec.

It may be shown that the change in phase of the klystron oscillation during this delay time is:

$$\theta_r = \frac{2\pi . xV}{W_r} \sin \frac{W_r T_d}{2} \text{ radians} \quad \ldots \quad \ldots \quad (5)$$

where θ_r = phase angle,
W_r = ripple frequency,
x = klystron reflector characteristic, cycles/volt,
V = peak-to-peak voltage of klystron reflector ripple,
and T_d = delay time.

Assuming full-wave rectification, and a 50 c/s supply, $W_r = 200$.

If the maximum error is not to exceed 1°, or $\frac{2\pi}{360}$ radians, then:

$$V \ngtr \frac{10^6}{9x} \text{ volts}$$

The klystron in use is a CV.129, the reflector characteristic being approximately 2.5×10^5 cycles/volt. Therefore, V $\ngtr$ 500 millivolts peak-to-peak. This ripple voltage corresponds to a frequency deviation of about 125 kc/s, and the ripple from a stabilized power supply can be controlled well within this limit. The recording of a complete phase plot may take as long as fifteen minutes, and it is important that the klystron does not drift more than 125 kc/s during this period. Thus a highly stable power supply, and some form of cavity stabilization is required for the klystron. The Kelvin-Hughes High Voltage Power Unit, which is stable to one part in 10^6 has been found very suitable. The two units comprising this power supply can be seen in Fig. 9.

Recording System.—The recorder, which is shown in Fig. 5, consists of a long carriage arranged to move slowly across a piece of graph paper at a speed proportional to the dipole trolley speed. The carriage is driven by a synchronous motor operating from the same supply as the trolley motor. Mounted on the carriage is a pen which can be moved transversely across the carriage by the rotation of a screwed rod, the turning of the rod being directly related to the vertical movement of the rotating dipole. Geared to the velodyne motor, which raises or lowers the dipole, is an " M " type " step-by-step" transmitter (see Fig. 4) which is connected to an " M " type receiver motor, which turns the screwed rod. Thus the position of the pen is directly proportional to the position of the rotating dipole and a graph is drawn of the contours of constant phase of the aerial under test.

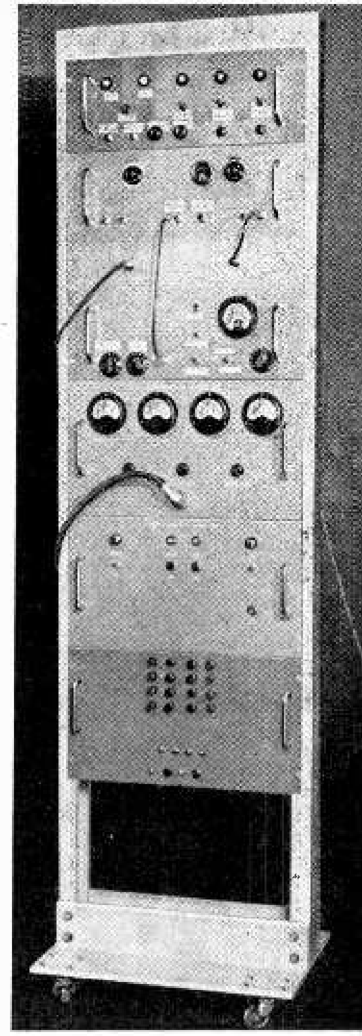


Fig. 9. Rack-mounted equipment. The units are (from top to bottom):—Railway control unit, selective amplifier, phase sensitive detector, velodyne amplifier, the two units of the klystron power supply, and finally the main power supplies.

Conclusions.—The equipment has been used successfully for phase plots of various types of X-band aerial. A limitation of the present system is that the pen movement can only follow contours of constant phase, and to obtain a plot of actual phase requires conversion from wavelength into phase angle. A direct plot of phase angle could be obtained by incorporating a variable speed gear in the " M " motor drive. A different ratio would be required to be set for each frequency, and then by choosing a suitable graph paper scale, degrees or radians would be indicated directly.

CORRECTION

On page 443 of our September 1960 issue, in referring to the " Lifeguard " products of Cathode Ray Tubes, Ltd., Factory Centre, Kings Norton, Birmingham 30, we inadvertently used a contraction which may have caused confusion with the firm of C.R.T. Ltd., Royston Road, Baldock, Herts, which has for some time now been engaged in the business of reconditioning cathode ray tubes.

We wish to express regret to both firms for any embarrassment which this may have caused.

Paris Radio Show: BROADCASTING AND ELECTRONICS

THIS year's exhibition, organized jointly by the Fédération National des Industries Electronique (F.N.I.E.) and the Radiodiffusion-Télévision Française (R.T.F.) was notable for the addition of a large section devoted to professional electronics and a considerable expansion of the facilities for the public presentation of live television and sound broadcasts. The F.N.I.E. has happily amalgamated the divergent interests of the manufacturers of domestic and professional equipment, and, in consequence, the exhibition presented a comprehensive view of the radio and electronics industry in France.

Television. The main hall, occupied by the domestic receiver manufacturers, seemed poorly lit by Earls Court standards and on a dull morning it was a little difficult to see what was on view in the recesses of some of the stands; but the logic of subdued ambient lighting became at once obvious when the day's television programme started. Judgment of picture quality could be made under conditions much nearer those of the home than is generally possible at Earls Court. The French 819-line standard presents no barrier to the current trend towards larger screens, and France definitely leads the race in this direction. Sales of 21-in sets are already on the point of overtaking those of 17-in, and large-screen (écran géant) receivers of 70-cm (27½-in) diagonal were offered by at least five firms. The tubes call for high e.h.t. supplies and some of these pictures were a little pale by comparison with adjacent 17-in and 21-in tubes, but no criticism could be levelled on the score of lininess. Three firms were showing sets with photo-cell automatic control of contrast.

A mains/battery receiver for use in cars and boats with 12-volt power supplies (shown by Télé-portable) was equipped with a 9-in tube, but the smallest television sets in the show made use of 1½-in tubes and were to be seen, faithfully reproducing the day's programmes, in a doll's house on the stand of Sonneclair. We have an idea that there was a good deal of auxiliary equipment out of sight in the cellars of this house!

Channel switching on most receivers includes a position for the proposed French "second chain" of television stations on u.h.f. Receivers with provision for the reception of one or both 625-line standards (Belgium and Luxembourg) in addition to the French national 819 lines are readily available, though most of the lower priced sets are for the French standard only. The question of price seems to be the first one asked by prospective customers at the Salon when they have been attracted to a receiver by the appearance of its cabinet, and discussion to the point of sale often continues without any sign of any picture on the screen. Good picture quality seems to be taken for granted by the French public—a remarkable tribute to the general technical competence of the receiver manufacturers and to the quality of the R.T.F. transmissions.

Styling in cabinet designs was in general conservative, though three or four of the larger firms showed a tendency to follow the slim rectilinear trends seen this year in other countries. There is no sign of the general adoption of plastic front-covers and most sets, even some portables, are fitted with heavy plate-glass implosion guards, detachable from the front for ease of cleaning.

Special programmes originating from the exhibition were radiated by R.T.F., from small glass-fronted studios and from the adjacent Palais des Sports (6,000 seats). One of the most popular was the "Jeu du Transistor" in which young enthusiasts were invited to assemble transistor receivers from kits of parts; the first to make his set work was allowed to keep it.

Of special interest in the R.T.F. technical exhibit was the latest mobile TV reporting link, used for the first time this year in following the Tour de France cycle race. A miniature TV camera unit (C.S.F.) and microwave link (492Mc/s, 400mW) was installed in a saloon car with sunshine roof. Its signals were transmitted vertically and picked up by a following helicopter and re-transmitted on 650Mc/s with a power of 5W and with, of course, much greater effective height. In this way fading troubles were eliminated and the number of relay points considerably reduced.

Sound. The emphasis in sound broadcasting this year was on *haute fidélité*. The coverage of f.m. stations in Band II has been considerably increased in France and a separate programme "France 4" now transmits high-quality music daily from 9.30 a.m. to midnight. There are also regular stereophonic broadcasts using two transmitters on Thursdays, Saturdays and Sundays. Even more interesting is an occasional stereophonic transmission on a single radio channel (90.35 Mc/s) from the Eiffel Tower using an experimental system developed by R.T.F. In this one audio channel is frequency modulated on the main carrier and the other amplitude modulated on a 70-kc/s sub-carrier. We were able to hear one of these experimental transmissions in a listening room at the High Fidelity Centre of the R.T.F. in the exhibition and the results were excellent, apart from a slightly higher background hiss than one has become accustomed to expect from a single-channel f.m. transmission.

As in most national radio shows there was a certain uniformity of cabinet styling, in conformity with the prevailing fashions. The small portables tend to be bright and colourful but here and there the quality of mouldings could be better. One point of design which commended itself and was seen in the majority of small radio sets was the push-button waverange selection with miniature stops no bigger than those used in an accordion.

Record players (électrophones) were offered in wide variety by a large number of small firms, and competition was keen. Stereo versions were common and in the better makes the practice was to provide two valises, one for the turntable and amplifier and the other dividing into two similar loudspeaker units with adequate baffle area.

Communications and Electronics. The French have always shown a marked flair for microwave techniques and they have established a considerable export business in microwave links (*faisceaux hertziens*). They also use them widely in their internal communications and in Africa, where developments in the Sahara have called for considerable extension of the services.

Equipment used in the new inter-continental television link between metropolitan France and Algeria was on show. This operates on 4kMc/s with 0.5kW into high-gain 6-metre reflectors which are shortly to be enlarged to 9 metres (e.r.p. 35MW). The total distance is 630km from Fontfrède to Algiers with one relay station at 4,500 ft in Majorca.

A replica of one of the new air traffic control desks now in use at Orly Airport was shown with a "live" radar display transmitted continuously by microwave repeater from Orly to the exhibition.

The organization of the electronics section in this its first year was excellent. Many firms had collaborated to display the whole range of the subject in its many aspects, and the group exhibits dealing with communications, national defence, nuclear energy, civil aviation, navigation, railways and automation were designed primarily to educate the public to a realization of the social and economic importance of electronics in France at the present time. Research and development as well as equipment already in production were shown, and one had the feeling that the representatives of the commercial firms and organizations contributing to the exhibits were as ready to explain the possibilities of electronics in general as to supply details of their own lines in particular.

The recruitment and training of personnel for the electronics industry is being pursued vigorously in France as in other countries, and the F.N.I.E. provided a special stand ("Formation Professionnelle") to give information on courses of instruction and the qualifications available to young people entering the industry. In addition to the normal engineering degrees from universities there are now the Certificate d'Aptitude Professionnelle (C.A.P.) awarded to apprentices who have also followed approved courses of study outside working hours, and the Brevet d'Enseignment Industriel (B.E.I.) for a somewhat longer course at a technical college. Various endorsements are possible for specialists in receiver alignment and fault finding, and for draughtsmen. Further study leads to the Brevet Professionnelle (B.P.) or Brevet de Technicien (B.R.) and the right to use the title "Agent Technique".

Electronics exhibits of Government departments and leading firms were grouped to demonstrate the contribution they make to the public service and industrial expansion.

COLOUR TELEVISION STANDARDS

Co-channel Interference and the Colour Sub-Carrier

By R. D. A. MAURICE*, *Ing. Dr., A.M.I.E.E.*

It is suggested that the half line-frequency offset commonly used or suggested for the N.T.S.C.-type colour sub-carrier is inferior to third line-frequency precision best offset from the point of view of interference from the colour sub-carrier in the luminance channels of colour and monochrome receivers. A diminution in extinction viewing distance of between 12% and 65% can be obtained by changing the offset of the colour sub-carrier from half line-frequency to third line-frequency, and the improvement in decibels can be given as between 4 and 9. Specifically it is suggested that the proposed colour sub-carrier frequency for the 625-line system be changed from 4,429,687.5 c/s to 4,430,800 c/s and that the number of lines per picture be changed from 625 to 627.

IT is well known[1] that for precision-offset working between television transmissions, the optimum results are not achieved when the unwanted carrier frequency differs from the wanted carrier frequency by exactly half or an odd multiple of half the line-scan frequency. Better results can be obtained when the difference between the unwanted carrier frequency and the frequency of the nearest line-harmonic sideband of the wanted signal is an odd multiple of the picture frequency. Such a relationship does not result in an invariant, odd or even, relation between the unwanted carrier and the picture frequency of the wanted signal, because odd line harmonics of the wanted signal have frequencies which are odd multiples of wanted picture frequency whilst even line harmonic frequencies are even multiples of picture frequency.

Using Hopf's[1] formulae, we have for the precision-offset best frequencies for an unwanted carrier

$$f_u = mf_L \pm (2n+1)f_P \quad \ldots \quad (1)$$

where f_u = frequency of unwanted carrier
f_L = line-scan frequency of wanted signal
f_P = picture frequency of wanted signal
m and n are integers, including zero
and $|f_u - mf_L| < f_L/2$

Now in all television systems (using interlacing) we have

$$f_L = (2q+1)f_P \quad \ldots \quad (2)$$

where q is integer

so $$f_u/f_P = m(2q+1) \pm (2n+1) \quad \ldots \quad (3)$$

and this ratio is odd when m is even and vice versa.

The above discussion refers to an unmodulated unwanted carrier, but it is not thought that the presence of unwanted modulation will affect to a material extent the proposals which follow.

In a colour transmission of N.T.S.C. type, the chrominance signal may be regarded, from the point of view of the luminance signal, as an unwanted carrier and it would, therefore, seem advisable to use a precision-offset best frequency for it. The present use of half line-scan frequency is, therefore, deprecated and following Hopf's[1] Figure 18, it would seem that a frequency differing from a line harmonic by about $\pm f_L/3$ would be optimum. Thus, letting the colour sub-carrier frequency be

$$f_{sc} = f_u$$

we may write $$f_{sc} = m f_L \pm (2n+1)f_P \quad \ldots \quad (4)$$

where $$(2n+1)f_P \simeq f_L/3 \quad \ldots \quad (5)$$

But from equation (2)

$$(2n+1)f_P \simeq (2q+1)f_P/3$$

so $$(2n+1)/(2q+1) \simeq 1/3 \quad \ldots \quad (6)$$

The following table shows some suggested frequencies for colour sub-carriers for several television systems. The master oscillator frequency which controls the line- and field-scan frequencies must be derived from the sub-carrier frequency and the

*Research Dept., Engineering Division, B.B.C.

[1] Hopf, H., "Experiments on the Operation of Television Transmitters with Precision Offset Carrier Frequencies," *Rundfunktechnische Mitteilungen*, December, 1958.

PROPOSED FIGURES: EQUATIONS (4), (5), (6) and (7)

System								
Lines/ picture	Fields/ second	$2q+1$	f_L (kc/s)	m	$2n+1$	$\frac{2n+1}{2q+1}$	f_{sc} (kc/s)	f_{sc}/f_M
405	50	405	10.125	262	+ 135	+ 1/3	2656.125	787/6
525	59.940052	525	15.734264	227	+ 175	+ 1/3	3576.9226	341/3
625	50	625	15.625	283	+ 207	$+\frac{1}{3+4/207}$	4427.050*	425/3**
627	50	627	15.675	283	− 209	− 1/3	4430.800	424/3

* $(283 + 1/3) f_L - 33\frac{1}{3}$ c/s.

** Actually $f_M = 3(f_{sc} + 33\frac{1}{3}$ c/s$)/425$

division ratios which are shown in the table are obtained by noting that the master oscillator frequency, f_M, is

$$f_M = 2f_L$$

and the division ratio results immediately:

$$f_{sc}/f_M = [m + (2n + 1)/(2q + 1)]/2 \quad .. \quad (7)$$

It will be seen from the table that the suggested new colour sub-carrier frequencies do not differ greatly from those either in use at the moment or agreed internationally for prospective use. Except for the 625-line, 50-field system there is no difficulty in obtaining the master oscillator frequency from the sub-carrier frequency; division by large prime numbers such as 787 presents no difficulties in the present state of the art. The 625-line system is unfortunate in that 3 is not a factor of 625, or $2q + 1$, in general terms. This lack is the cause of the quantity 4/207 which appears in the denominator of $(2n + 1)/(2q + 1)$ for the 625-line system and this term, in turn, is the cause of the need to add 33⅓ c/s to the sub-carrier frequency before dividing by 425 and multiplying by 3 to obtain f_M, as shown in the footnote(**) to the table. The inclusion of a separate source of frequency for supplying the 33⅓ c/s is undesirable and complicates the frequency-generating equipment required to obtain the master oscillator frequency from a crystal-controlled sub-carrier source.

It is, therefore, suggested that European agreement be obtained for a change in both the proposed 625-line sub-carrier frequency and in the number of lines per picture, thus:

Sub-carrier frequency from 4,429,687.5 c/s to 4,430,800 c/s, *an increase of* 1,112½ c/s

Number of lines per picture from 625 to 627§

The master oscillator frequency would then be obtained from the colour sub-carrier frequency by division by 424 followed by multiplication by 3.

It has been shown experimentally that this change improves markedly the compatibility of the colour television system, and it allows the future use of precision best offset between television transmissions with the least complexity of waveform-generating and feed-back type carrier-locking equipment, should precision offset be desired in the u.h.f. bands. The only disadvantage of using 1/3rd line offset instead of 1/2 line offset for the colour sub-carrier is the very slight increase in susceptibility to "side-locking" in colour receivers. It is thought that this will, however, be negligible.

The beat pattern between sound and chrominance carriers will be reduced in like manner to the colour sub-carrier and it is not necessary to make any changes in existing relationships which may have been established between wanted sound and wanted vision carriers in certain colour television systems.

It should be pointed out, perhaps, that the suggested change from 625 to 627 lines is not essential to the use of precision-offset best frequencies for colour sub-carriers or other interfering signals, but it does render the equipment required to achieve 1/3rd line offsetting simpler and more reliable. The table shows the appropriate sub-carrier frequency for the 625-line system, should international agreement to change it to 627 lines be difficult to achieve.

§This change was suggested by Mr. G. F. Newell.

PRESENT FIGURES: $f_{sc} = (r + 1/2)f_L$

r	f_{sc} (kc/s)	f_{sc}/f_M
262	2657.8125	525/4
227	3579.545	455/4
283	4429.6875	567/4
283	4443.8625	567/4

Experimental Confirmation

An experiment was set up using equipment which had been in use for extensive co-channel interference tests. Two levels of unmodulated interfering carrier at about 2½ Mc/s were used in a 405-line, 50 field closed-circuit monochrome video test using a 21-in monitor. Reference to the table shows that exactly 1/3rd line-frequency offset is satisfactory for the 405-line system,

$$[(2n + 1)/(2q + 1) = 1/3]$$

The 2½ Mc/s carrier was meant to represent a colour sub-carrier and the two levels of interference used corresponded with (i) the ratio of chrominance to luminance during transmission of fully saturated red at maximum brightness and (ii) maximum chrominance signal with reference to peak white. The two levels of interference, although differing quantitatively in appearance, gave the same subjective improvement when the frequency of the simulated sub-carrier was changed from the half line-frequency offset to the one-third line-frequency offset. The results will, therefore, be presented without further reference to the ratio of chrominance to luminance.

Although several observers were present during the tests, only the writer recorded his opinions. These took two forms: the improvement ratio in decibels and the viewing-distance improvement as a ratio of interference extinction distance. The form of the interference was also dual in the sense that there was the well-known dot pattern and, with a particular slide showing a girl holding a fan with fine tracery on it, there was severe flickering (with the sub-carrier in the half line-frequency condition) which was representative of the monochrome compatible equivalent of cross-colour. An interesting feature of interference resulting from an unwanted signal at a precision best offset is the absence of pattern movement or dot crawl which is so evident at the half line-frequency offset.

For the *dot-pattern* interference the ratio of extinction viewing distances was

$$\frac{\tfrac{1}{3}\text{rd line}}{\tfrac{1}{2}\text{ line}} = \frac{12\tfrac{3}{4}\text{ft.}}{14\tfrac{1}{4}\text{ft.}}$$

or 12% improvement.

The improvement in the ⅓rd line-frequency condition measured in decibels was between 4 and 5 dB.

For the *flickering cross-colour* type of interference the ratio of extinction viewing distances was

$$\frac{\tfrac{1}{3}\text{rd line}}{\tfrac{1}{2}\text{ line}} = \frac{12\tfrac{3}{4}\text{ft.}}{21\text{ft.}}$$

or 65% improvement.

The improvement in the ⅓rd line-frequency condition measured in decibels was 9 dB.

The author wishes to thank the Director of Engineering of the B.B.C. for kind permission to publish this paper.

Elements of Electronic Circuits

19.—GATES AND COINCIDENCE CIRCUITS

By *J. M. PETERS*, *B.Sc. (Eng.), A.M.I.E.E., A.M.Brit.I.R.E.*

A COINCIDENCE circuit delivers an output when one or more independent inputs coincide or occur at the same time. This is a general term for describing the class of circuit and consequently covers cases where the output bears little resemblance to any of the inputs. For instance, the amplitude and/or shape of the output waveform may not necessarily be the same as the input waveforms.

A gate circuit is a particular class of coincidence circuit where it is essential that the output waveform should closely resemble the input waveform. When the gate is "open" it is required to pass the input with the minimum of distortion; when it is "shut" there should be no output.

Gate circuits can be further sub-divided. Two important classifications are "and" gates and "or" gates, the significance of the terms being appreciated if the symbols in Fig. 1 are examined. Fig 1 (a) illustrates in diagram form a circuit which has, for example, two inputs and one output. When signals are present simultaneously at both inputs then an output signal is delivered.

The numeral 2 is written inside the circle to denote the fact: this circuit is called an "and" gate. A more general symbol sometimes encountered is that in Fig. 1(b) which represents a circuit with n input sources but which only delivers an output when x (in number) sources are supplying inputs. It follows therefore if $x=n$ the circuit is an "and" gate. Fig. 1(c) represents a circuit again having two inputs, but in this case it is only necessary for one input signal to be present for an output signal to be delivered. As with the previous symbol, the numeral 1 is written inside the circle to denote the fact. This circuit is called an "or" gate. The general symbol for an "or" gate is shown in Fig. 1 (d). Here $x=1$ and the line is carried through the symbol to denote the preservation of the characteristics of the input waveform.

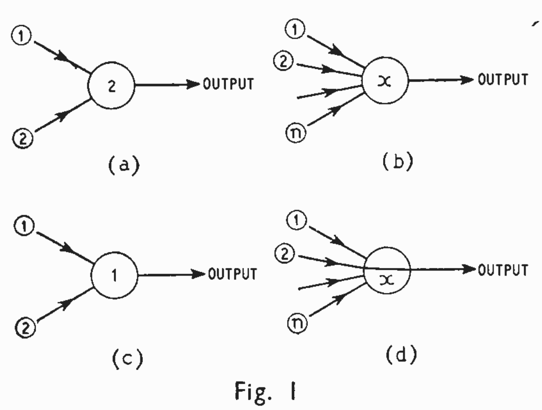


Fig. 1

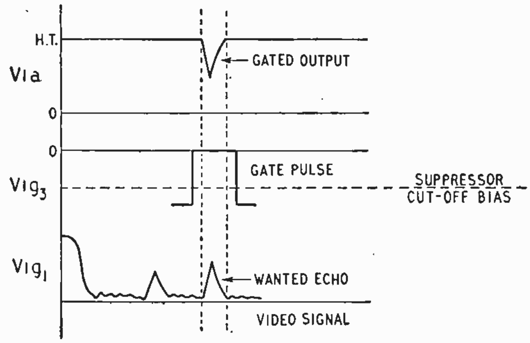


Fig. 2

Practical Forms

Now let us examine the form and use of some coincidence and gate circuits. One of the widely used gate circuits involves a multi-electrode valve, the control electrodes of which are biased to prevent anode current flowing. The positive inputs are applied to the control electrodes, which in a pentode are control grid and suppressor grid, and when both signals are present simultaneously anode current flows. When used as a true gate circuit as opposed to a coincidence circuit, a positive gate or square wave pulse applied to the suppressor grid "turns the valve on" for the duration of the pulse. Provided that the valve is biased just below grid cut off, the gate pulse will introduce very little distortion. The output therefore closely resembles the input signal, which is a necessary requirement of a gate circuit.

Radar receivers often include gate circuits of this type to select a particular target echo from a number of target echoes or background clutter. The output from the timebase generator is fed to a gate pulse generator which produces a short positive pulse as the c.r.t. spot passes the range marker. The duration of the pulse is a little longer than the received echo and is applied to the suppressor grid of the pentode gate valve (see Fig. 2). The video signal comprising ground return, wanted and unwanted echoes, is applied to the control grid of the pentode. Although the control grid is taken above cut-off by the video signal, no anode current flows until the positive-going gate pulse arrives at the suppressor grid and raises it above suppressor cut-off. The positive pulse coincides with the wanted echo which therefore causes a negative-going voltage pulse to be produced at the anode; thus the wanted echo is allowed through the gate and the other echoes, etc., are rejected. Fig. 3 shows the gate circuit in which V1 is the gate valve. The diode clamp V2 is inserted to prevent the gate pulse from driving

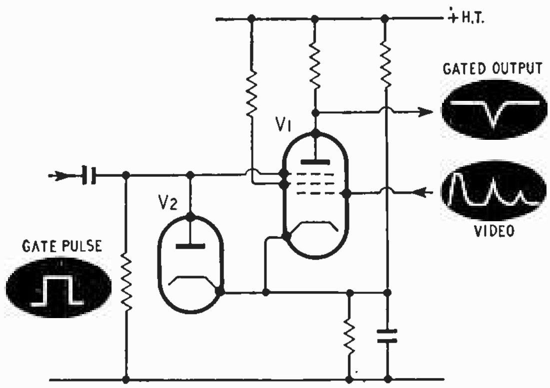


Fig. 3

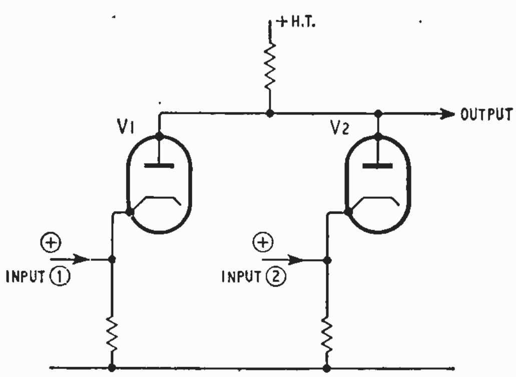


Fig. 4

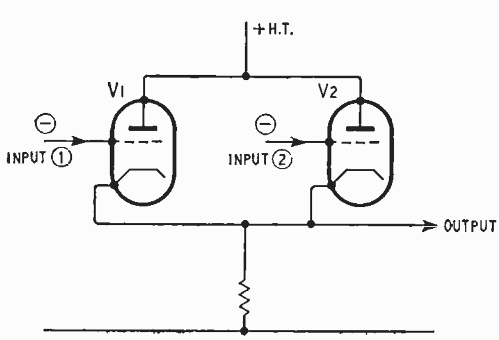


Fig. 5

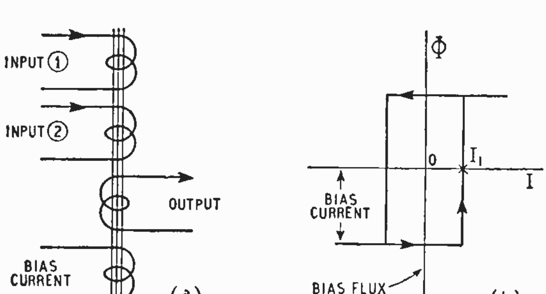


Fig. 6

the suppressor grid positive with respect to the cathode.

Another example of an "and" gate is shown in Fig. 4. Crystal diodes may be used here in preference to valves. The application of a positive signal, Input 1, to the cathode of V1 cuts off the current flowing in V1. Although this causes the current in the second valve to double, the result is a negligible increase in output voltage. When Input 2 is in coincidence, however, the output is greatly increased. An alternative version of this circuit may be encountered in which the diodes and the supply voltage are reversed. The input signals would then be negative-going.

When describing the action of the long-tailed pair or cathode inversion circuit (No. 5 of this series, p. 911, Sept. 1959), it was shown that the common cathode voltage always tended to follow the more positive grid. This configuration can also be used as a coincidence circuit (Fig. 5). Suppose we apply negative signals to both grids, the voltage at the common cathode can only swing negative if both input signals are present simultaneously. Alternatively, a gate pulse can be applied to one of the grids thus transforming it into a gate circuit.

Current-operated Gates

In all the above examples we have considered the gate as an acceptor or rejector of voltage signals or pulses. We must not overlook the fact that current gates are also widely used. One type of current gate involves the use of a magnetic core with a rectangular hysteresis loop. The several positive inputs are applied to a number of windings on the core upon which is wound the output coil Fig. 6(a). The core is "biased" by a reverse-polarity current flowing through one of the windings. The bias produces an opposite flux which is only overcome when the sum of the currents in the other windings exceed a value shown as I_1 in Fig. 6 (b). The gate is now open and a current is induced in the output coil.

RADIO HOBBIES SHOW

List of Exhibitors

THIS year's International Radio Hobbies Exhibition, sponsored by the Radio Society of Great Britain, opens at the Royal Horticultural Society's Old Hall, Westminster, London, on November 23rd for four days. As will be seen from the appended list, exhibitors include manufacturers and suppliers of equipment for the amateur fraternity, publishers and amateur organizations, as well as the Armed Forces. A feature of the exhibition, which will be open daily from 11 to 9 (admission 2s) is the display of typical transmitting rooms, some with home constructed equipment and others with commercial gear.

As already announced, Brian Rix, the well-known actor who is also a radio amateur (G2DQU), will open the Show.

A.E.I. (Woolwich)
Avo
Bridge Electronics
British Amateur TV Club
Data Publications
Daystrom
Electronic Technology
Electroniques (Felixstowe)
Enthoven Solders
Jason Motor & Electronic Co.
K.W. Electronics
London U.H.F. Group
Minimitter
Mullard
R.S.G.B.
Royal Air Force
Royal Naval Reserve
Royal Signals T.A.
Scott, James, & Co.
Short Wave Magazine
Sound Vision Service
Taylor Electrical Instruments
Tiger Radio
Webbs Radio
Wireless World
Withers Electronics

WORLD OF WIRELESS

Mobile Radio

THE Fourth Report of the Mobile Radio Committee set up by the P.M.G. is concerned with recommendations for reducing to 25kc/s the channel spacing in the mobile radio "high" band (165 to 173.05Mc/s). The Committee's Third Report, issued in March, 1959, proposed a similar reduction of channel spacing in the "low" band (71.5 to 88Mc/s).

The situation in the high band is, however, rather complex, for the reduction of channels from 100 to 50kc/s in accordance with the Committee's Second Report of July, 1956, has not yet been completed.

The Committee has revised the distribution of channels amongst the various categories of users, and a diagram showing the new allocation is included in the Report.

The changeover to the narrower channels begins on January 1st. Thereafter, all new land-mobile systems in the high band will have to use equipment meeting the 25-kc/s specification. With few exceptions, the 25-kc/s standard will also apply to replacements of equipment for existing services.

Pilkington Committee

THE Committee on Broadcasting, set up under the chairmanship of Sir Harry Pilkington, has invited any person or organization desirous of submitting evidence or making representations to the committee to communicate with the secretary not later than November 30th. The committee, which originally had an office in the G.P.O. Headquarters, is now at Cornwall House, Waterloo Road, London, S.E.1, to which address communications should be sent. The committee's terms of reference are:—

"To consider the future of the broadcasting services in the United Kingdom, the dissemination by wire of broadcasting and other programmes and the possibility of television for public showing; to advise on the services which should in future be provided in the United Kingdom by the B.B.C. and the I.T.A.; to recommend whether additional services should be provided by any other organization; and to proposed what financial and other conditions should apply to the conduct of all these services."

"Marconi House"

THESE words have been removed from the well-known building in the Strand, London, which now forms part of the new English Electric House built on the adjacent site of the old Gaiety Theatre. For such an historic building to lose its identity is indeed regrettable. It is, of course, realized that the Marconi companies are now part of the English Electric Group and, too, that there is a plaque on the outside wall of the building recording that the first station of the British Broadcasting Company operated within the building, but even so, it has lost its identity—at least for future generations.

The change of title will not involve the movement of the various departments of the Marconi companies occupying offices in the building.

B.B.C. Report

IT is difficult to give extracts from the 175-page Report of the B.B.C. for 1959/60* without giving undue prominence to what may be a comparatively insignificant part of the whole. However, here are some facts and figures.

V.H.F. Coverage.—About 97% of the population are within range of the v.h.f. sound broadcasting service but only an estimated 20% of the households have v.h.f. sets.

A Third TV Service?—Some 750,000 people are still without a television service. The B.B.C. suggests that instead of utilizing the "uncommitted channels in Band III" to provide a third television service for those already with a choice of two, "a better use would be to strengthen the coverage of the existing television services." Nevertheless "it remains the B.B.C.'s objective to provide the public with a planned choice between two different television programmes as soon as possible." The Report reiterates that "if the Government so decided the B.B.C. would be ready to start a service of colour television in Bands I or III."

Revenue.—The gross revenue from broadcast receiving licences for 1959/60, excluding the £1 excise duty, was £36,209,680. The Post Office deducted £2,394,060, the Treasury retained £2,529,467, leaving the B.B.C. £31,286,153. The B.B.C. also received a grant-in-aid of £6,679,000 for its External Services.

Expenditure.—Of the £11.9M revenue expenditure on the Sound Services, £2.77M was for engineering. Revenue expenditure for television was £15.8M (engineering £5M) and for External Services £6.4M (engineering £1.6M).

* Cmnd 1174, H.M.S.O., 9s.

Student Apprentices

THE student apprenticeship scheme inaugurated by the Post Office last January drew over 1,000 enquiries, which resulted in some 600 applications for consideration for the 20 places. Two hundred of the applicants—between the ages of 17½ and 20—were eventually interviewed.

The scheme provides for a year's training in telecommunications engineering, and three years at a University, all fees and subsistence being paid under the award. The successful candidates are:—

M. Elliott (Kings School, Canterbury); T. R. Marsh (Leeds Grammar S.); A. D. King (George Watson S., Edinburgh); A. E. Fantom (Stockport Grammar S.); A. Wright (Ilkeston Grammar S., Derby); D. G. Leyton (St. Julians High S., Newport, Mon.); M. J. Colles (Canford S., Wimborne, Dorset); A. Thomas (Stretford Grammar S., Manchester); J. S. H. Ross (Dame Allens S., Newcastle); B. Ray (Slough Grammar S.); N. A. Cumpsty (Haberdashers Askes S., London); D. J. C. de Mesquita (Owens S., London); M. Crabtree (King Edward VI S., Stourbridge); T. G. Simmonds (Exmouth Grammar S.); J. C. Berry (Bolton S.); T. F. Smith (St. Albans S., Herts.); J. A. Beattie (Devonport High S., Plymouth); M. R. Miller (Watford Grammar S.); N. J. E. Reynolds (Queen Elizabeth S., Barnet); D. W. McLachlan (Wrekin College, Wellington, Salop).

Ultra Scholarships.—Ultra Electronics, Ltd., have awarded three two-year research scholarships instead of the one originally announced last March, because it was found difficult to select only one from the large number of applications received from graduates of a very high calibre. The recipients are: D. E. Hirst, of Barkingside, Essex, who obtained 1st class houours in engineering at Kings College, University of London, where he will undertake research on microscopic measurements by electronic/optical means; W. P. Williams, of Meols, Cheshire, who graduated with 1st class honours in engineering at Nottingham University and will carry out research on computer systems using ternary devices at the University; and D. A. Green, of Leeds, Yorks., who obtained 2nd class honours at University College, University of London, will carry out research on electronic means of producing synthetic speech in the Department of Anatomy. The company also awarded a sandwich scholarship to R. A. Greenbaum, of Hendon, London. He has been accepted in the Electrical Engineering Department of Sheffield University as from Autumn, 1961, and has joined Ultra Electronics for 12 months' practical work.

Institute of Navigation.—This year's gold medal of the Institute of Navigation is awarded to Captain F. J. Wylie, R.N., director of the Radio Advisory Service of the Chamber of Shipping and Liverpool Steam Ship Owners' Association, for "his outstanding contributions, made over a number of years, to the art of radar-assisted navigation at sea". Capt. Wylie was president of the Institute for 1958/59. The Institute's bronze medal is awarded to W. J. Charnley, of the Blind Landing Experimental Unit of R.A.E., for his paper "Blind landing". G. E. Beck, of Marconi's, who contributed an article on airborne Doppler navigation in our May, 1957 issue, has been elected a Fellow of the Institute. The annual report of the Institute records that the membership increased during 1959/60 by 129 to 1,883.

R.T.E.B.—Of the 642 candidates who sat for the television servicing examination held by the Radio Trades Examination Board earlier this year, 298 qualified for the certificate, 248 failed and 96 have to re-take the practical test next year. The total number of candidates was 179 more than last year. Only the written part of the sound radio servicing examination was taken in May. Of the 1,715 entrants, 1,253 were successful. These, together with 330 candidates who were "referred" in last year's practical test, sat for the practical examination in October.

Brookman's Park's New Transmitter.—The B.B.C. has ordered from Marconi's a new 50-kW medium-wave transmitter to replace the existing Light Programme transmitter at Brookman's Park installed 31 years ago.

"**Modulation and Modulators**" is the latest colour filmstrip introduced by the Mullard Educational Service. The first part of the 30-frame strip deals with the various types of modulation and the second with practical methods of achieving them. It is available from the distributors, Unicorn Head Visual Aids Ltd., 42 Westminster Palace Gardens, London, S.W.1, price 25s, including comprehensive teaching notes.

Careers.—A booklet "Careers in the Scientific Industry" has been issued by the Scientific Instrument Manufacturers' Association, which gives, in addition to background information on the industry, a geographical directory of 170 member firms of the association.

"**Piezoelectric Voltage Transformers**".—On page 513 of the October issue, the voltmeter input capacitance (last paragraph of left-hand column) should, of course, be 10 pF (not μF). Similarly, the transformer output capacitance is 40 pF (not μF).

Faraday Lecture.—The subject of the 1960/61 Faraday Lecture of the I.E.E. is "Transistors and all that" which will be given by L. J. Davies, director in charge of research and education of A.E.I. (Rugby). The lecture will be delivered first at Rugby (on November 16th) and then at a number of provincial centres before being given at the Central Hall, Westminster, London, on February 16th. Tickets, obtainable free, are needed for each meeting. Those for the London meeting can be obtained from the I.E.E., Savoy Place, W.C.2.

Weather Ships.—The nine weather ships in the north Atlantic supplied and maintained by 18 countries whose airlines fly across the Atlantic, made radio contact with 51,577 aircraft and 14,791 ships during 1959. They also provided 45,980 radar fixes for transatlantic aircraft and 3,396 d.f. bearings. These figures are given in the report of the International Civil Aviation Organization on the ocean stations network.

N.E. England is to have its own electronic engineering exhibition next year. Organized by the North East Industrial Development Association, it will be held in Newcastle from February 28th to March 2nd. Over 20 companies and colleges have already taken space.

A.E.R.E. Harwell.—A solid-state physics division has been formed at the Atomic Energy Research Establishment, Harwell. Its initial term of reference will be: to carry out basic research leading to greater knowledge and understanding of the structure and behaviour of solids. Dr. W. M. Lomer, at present head of the theoretical physics division, has been appointed head of the new division.

International Symposium.—"Electromagnetics and fluid dynamics of gaseous plasma" is the subject of the 11th international symposium organized by the Polytechnic Institute of Brooklyn, which will be held in New York City from April 4th to 6th next year.

Television licences in the U.K. increased during September by 63,422, bringing the total to 10,880,470. Sound-only licences totalled 4,296,246, including 456,292 for sets fitted in cars.

School Television.—The number of schools registered with the U.K. School Broadcasting Councils for school television programmes is now 2,287.

Can You Help?—A reader in Mauritius requires a circuit diagram of the Hartley-Turner 20-W amplifier. Information addressed to A. Domaingue, care of the Editor, will be forwarded.

CLUB NEWS

Cleckheaton.—"Receivers for f.m." is the title of the talk to be given by F. L. Allen (G3CJD) to members of the Spen Valley Amateur Radio Society on November 23rd. Meetings are held on alternate Wednesdays at 7.30 at the Labour Rooms.

Halifax.—At the November 1st meeting of the Halifax and District Amateur Radio Society C. B. C. Hill (G3LGS) will speak on single sideband operation. The club meets on alternate Tuesdays at 7.30 at the Sportsman Inn, Ogden.

Mitcham and District Radio Society is to have a lecture-demonstration by Collins Radio Co. on November 18th. Meetings are held at 8.0 at "The Cannons," Madeira Road.

Reading.—Ampex are providing a lecture-demonstration of their video tape recording equipment for the Calcot Radio Society on November 25th at 7.45 at St. Birinus Church Hall, Calcot.

South Kensington.—A. F. Wilkins, an early member of Sir Robert Watson-Watt's radar team, is to give a talk entitled "The beginnings of radar" at the meeting of the Civil Service Radio Society at 5.30 on November 1st. Visitors are welcome, but should contact G. C. Voller at the Science Museum (Tel.: Kensington 6371).

Personalities

H. Stanesby, C.G.I.A., M.I.E.E., the new Deputy Director of Research at the Post Office, has been staff engineer in the radio planning and provision branch of the Engineering Department since 1952. He joined the Radio Laboratories at Dollis Hill as a youth-in-training in 1924 and in 1951 was made responsible for the direction of the laboratories. He was intimately concerned with the development of the first long-wave transatlantic radio-telephone system. He later played an important part, especially in the design of quartz crystal filters, in developing coaxial cable systems for multi-channel telephony. Mr. Stanesby, who is 54, was chairman of the Radio and Telecommunications Section of the I.E.E. in 1955/56.

H. Stanesby.

Dr. T. W. Straker.

Dr. T. W. Straker, chief of the projects co-ordination group of Marconi's Research Division, has been appointed manager of the company's Radar Division. A New Zealander, he took his B.Sc. (and later, in 1938, his M.Sc.) at Canterbury University College, where he was engaged on researches on the absorption of h.f. radio waves in the ionosphere. After war service he returned to New Zealand as assistant lecturer in physics at Canterbury University. A year later, in 1946, he came to this country to study at the Cavendish Laboratory, his particular subject being research in the ionospheric propagation of low-frequency radio waves. He took his Ph.D. in 1950 and that year joined the Defence Research Board of Canada. In 1954 he was appointed Defence Research Liaison Officer, Canadian Joint Staff in London. Dr. Straker joined Marconi's in 1957.

Among the dozen or so special promotions of "research workers of exceptional merit" in the Scientific Civil Service are: **R. Benjamin** (A.S.E.) and **Dr. L. Essen** (N.P.L.), who became Deputy Chief Scientific Officers, and **W. R. Piggott** (D.S.I.R.) who is appointed Senior Principal Scientific Officer. Mr. Benjamin, who is 37, joined the Admiralty Signal Establishment in 1944. His particular fields of research have been in pulse techniques and more recently in automation and computation as applied to data processing and weapon control in naval warfare. He has played a major part in the latest naval 3-D air defence system. Dr. Essen is well known for his work on precise frequency standards and more recently for introducing the caesium atomic beam resonator as a standard of time. Mr. Piggott, who joined the D.S.I.R. in 1939, has made an intensive study of the absorption of radio waves by the ionosphere. His studies of the upper atmosphere have also influenced the design of aerials to take the best advantage of the ionosphere for long-distance communications.

Air Commodore A. T. Monks, C.B., M.I.E.E., Controller of Telecommunications at H.Q., Signals Command, R.A.F., for the past five years, has been appointed Senior Air Staff Officer, Technical Training Command, with the acting rank of Air Vice-Marshal. Air Commodore Monks, who is 52, joined the R.A.F. as an aircraft apprentice in 1924 and became a signals specialist in 1940. Among the appointments he has held since the war are those of Deputy Director of Telecommunications, and Deputy Director of Signals (Ground) at the Air Ministry, C.O. of Nos. 4 and 1 Radio Schools and Chief Signals Officer at H.Q., Allied Air Forces Northern Europe.

George A. Smith, until recently general manager of the Telecommunications Division of the Plessey Company, has been appointed commercial executive of the company's Electronic and Equipment Group. This group includes the telecommunications, electronics and domestic equipment divisions and Hagan Controls Ltd., employing in all over 4,000 people. Before joining Plessey in 1957, Mr. Smith was for ten years with the telecommunications division of Pye Ltd.

In consequence of the recent acquisition of the Telephone Manufacturing Company by Pye, three directors of the Pye Group have been appointed to the board of Temco. They are **R. M. A. Jones** (vice-chairman), **Sir Ben Barnett** and **J. R. Brinkley.**

Horace Freeman, who has been associated with radio publicity since the early 1920's and was for very many years advertisement manager of the R.S.G.B. publications, has resigned from the National Publicity Company, with which his own agency was merged in 1951. Mr. Freeman was closely associated with the staging of the first all-British wireless exhibition in London in 1922 and was manager of many of the amateur radio shows sponsored by the R.S.G.B.

Hedley J. C. Gower, A.M.I.E.E., has been appointed chief engineer of Border Television Ltd., the I.T.A. programme contractors for the Scottish / English border area. The station is at Caldbeck, near Carlisle. He commenced his career with E.M.I. and then joined the B.B.C. After war service he returned to the B.B.C. where he stayed until going to Granada Television in 1955 as head of O.Bs. He is 43.

H. J. C. Gower.

OUR AUTHORS

David S. Wilde, B.Sc., A.M.I.E.E., Grad.Inst.P., who writes in this issue on digital computers, is a senior project engineer with E.M.I. Electronics, Wells, Somerset, where for the past three years he has been working on digital data processing equipment. After nearly three years in the Royal Navy as a radar mechanic, he went to Manchester University where he graduated in physics in 1951. On leaving the University he joined the computer group of Ferranti, and three years later went to the electronics laboratory of A. V. Roe and Co., where he stayed until 1957 when he joined E.M.I.

C. Maxwell Cade, who with A. T. Elliott, describes an automatic microwave aerial plotter in this issue, has been with Kelvin and Hughes since 1954 and is now deputy head of the Radar Department. He originally studied medicine at Guy's Hospital Medical School.

taking the 1st M.B. in 1940. He was invalided out of the R.A.F. in 1942 after two years' service and joined the M.O. Valve Company as a technical supervisor. From 1951 to 1954 he served as an experimental officer in the Royal Naval Scientific Service at the Services Electronics Research Laboratory, Harlow, Essex. In 1959 Mr. Cade received the Navigation Prize of the Royal Aeronautical Society for a paper on radio astronomy and navigation and this year was a recipient of one of the R.I.C./E.E.A. technical writing premiums. He is 42.

C. M. Cade.

A. T. Elliott.

A. T. Elliott, co-author of the article on p. 530, has been with Kelvin and Hughes since 1947 except for two years' National Service when he was an instructor in radar techniques at the R.A.F. Radio School, Yatesbury. He rejoined the company as a radar development engineer and since 1956 has been a senior engineer leading a development group concerned with microwave and infra-red devices.

F. R. B. Jones, the first part of whose article on nodal analysis appears on p. 556, is a civilian lecturer at the R.E.M.E. Training Centre, Arborfield, Berks. During the war he specialized in radio and radar in the Army and was at one time Brigade Radio Officer and at the time of his demobilization was Telecommunications officer in 7 Base Workshop, Alexandria. From 1945 until 1952, when he went to Arborfield, he was a teacher.

J. P. Hawker, who contributes the article on amateur radio developments in this issue, obtained his first transmitting licence (2BUH later G3VA) in 1936 when he was 14. He edited the latest edition of the R.S.G.B. "Guide to Amateur Radio."

OBITUARY

Sir George Barnes, M.A., D.C.L., who died at the age of 56 on September 22nd, was for 21 years with the B.B.C., which he left in 1956 to become principal of the University College of North Staffordshire. Sir George was the first Head of the Third Programme. For the last six years of his service with the Corporation he was Director of Television. Since 1958 Sir George had been president of the Television Society.

Sir Arthur Fleming, C.B.E., Director of Research and Education of Metropolitan-Vickers for many years before assuming a similar position with the parent company, Associated Electrical Industries, from which he retired a few years ago, died on September 14th, aged 79. Sir Arthur joined Metrovick in 1902.

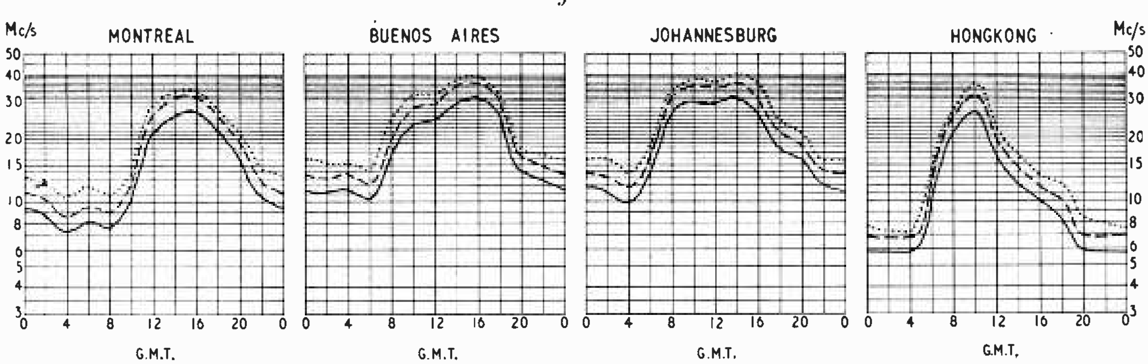
W. J. Chalk, B.A., who was in charge of the Frequency Allocations Section of the B.B.C.'s Engineering Information Department, died suddenly on September 24th, aged 61. He served throughout the war in Royal Signals, holding a number of staff appointments as Radio Planning Officer in Europe and the Middle and Far East. He was a member of the Allied Control Commission in Germany. Mr. Chalk joined the B.B.C. in 1951 and represented the Corporation on a number of national and international technical committees concerned with frequency allocation and radio interference problems.

George E. Turnbull, a director of W.N.A. (Wireless Navigational Aids) Ltd., who died on September 17th, had been associated with the radio industry since 1902 when he joined the Marconi Company. In 1924 he became director of the International Marine Sounding Device Soc. Ame., of Brussels.

E. T. W. Barnes, manager of manufacturing, A.E.I. Electronic Apparatus Division, New Parks, Leicester, died on September 19th. He was 54. He joined Metropolitan-Vickers, now A.E.I. (Manchester), in 1930 as a college apprentice and was at one time superintendent of the company's Radio Department.

SHORT-WAVE CONDITIONS

Prediction for November



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

— — — PREDICTED MEDIAN STANDARD MAXIMUM USABLE FREQUENCY

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

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

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

News from Industry

A.T.V.—The group profit of Associated Television, Ltd., programme contractors for the I.T.A. London and Midland stations, for the year ended on April 30th, was £5,388,330 as compared with £5,316,493 in the previous year. Taxation took £2,711,820 as against £2,715,076. Muzak, Ltd., suppliers of recorded background music, are a subsidiary of the group, which also has a 50% holding in Pye Records and an interest in British Relay Wireless and Television, Ltd.

Sobell-McMichael.—A record trading profit of £1,325,735 is recorded by Michael Sobell, the chairman of Radio and Allied (Holdings) Ltd., in his statement for the year ended last April. The profit after taxation was £655,107. Reference is made in the report to the company's acquisition in April of Masteradio Ltd.

E.M.I's group profit for the year ended in June (before taxation) was £5,348,000 compared with £4,909,000 the year before. U.K. and overseas taxation absorbed £2,714,000 (£2,534,000) which after small adjustments left a group net profit of £2,413,000 (£2,232,000).

Multisignals Ltd., formed jointly by Thorn Electrical Industries, E. K. Cole, Ultra and Anglia Television to promote wired television installations, announce that the Granada group has become a 20% shareholder. Multisignals operates in association with the Radio and Television Retailers' Association.

Ampex.—The name of the company marketing Ampex magnetic recording equipment in the U.K has been changed from Redwood City Engineering Ltd. to Ampex (Great Britain) Ltd. Its offices are in Reading, Berks, adjacent to those of Ampex Electronics Ltd., the British manufacturing company. Both companies are subsidiaries of Ampex International, S.A., of Fribourg, Switzerland. Excluding the U.S.A. where there are 484 video tape recorders in use, the U.K. has the second largest total—46. Canada has 49 and Japan 35.

Hughes International (U.K.) Ltd., the recently formed associates of the Hughes group of America, are now producing semiconductors at their new factory at Glenrothes, Fife. Initially the staff is 80 but it is planned to be increased to 350 by the end of next year. The general manager is David Simpson, for some time research engineer in Marconi's radar division and more recently general manager of Microcell Ltd. George D. Scott, until recently with Ferranti, is chief engineer, and William J. Symes, formerly a transistor development engineer with Associated Transistors Ltd., is assistant chief engineer.

Emidicta.—A further supply of Emidicta telephone answering machines, making nearly 100 in all, has been ordered by the Post Office from E.M.I. Sales and Service. They are used for the various telephone information services—TIM, WEA and ASK—provided by the G.P.O.

Pye TVT, Ltd., equipped Eastern Nigeria's first television station which was opened on Nigeria's Independence Day, October 1st. The station, situated at Enugu, also incorporates a commercial sound broadcasting transmitter.

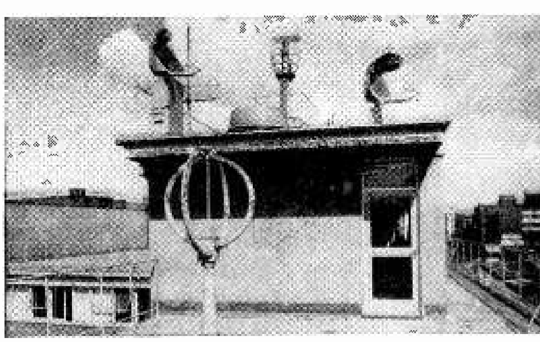
KABI, the trade name of Precision Components (Barnet) Ltd., of Potters Bar, Middx., is incorporated in the company's new title which is KABI (Electrical and Plastics) Ltd.

Radio and Television Trust, which was until last year a subsidiary of Crompton Parkinson Ltd., records a consolidated profit for the nine months ended last March of £118,060. This figure includes £25,742 in respect of three months' profits of British Communications Corporation, which was taken over by the company in January. The net profit after taxation for the nine months is £65,816 compared with £71,533 for the previous 15 months. Airmec, Ltd., of High Wycombe, is also a subsidiary of the company.

S.T.C. provided the complete cable system, including 530 nautical miles of submarine cable, 29 submerged repeaters, submerged equalizers and terminal equipment, for the first direct U.K.-Sweden telephone cable link inaugurated on October 11th. It employs a single cable for both directions of transmission. The repeaters provide for 60 two-way circuits of 4kc/s spacing.

Decca have announced the receipt of the 10,000th order for their marine radar—eleven years after they entered the marine radar market. The installation of 10,000 sets represents sales valued at some £18M, of which £11M worth has been exported.

Magnavox equipment, including record players, radio gramophones and later tape recorders and television sets, is once again being marketed in the U.K. Magnavox Electronics Ltd., of 129, Mount Street, London, W.1, has been formed to handle the equipment which initially is being manufactured by sub-contractors in this country. The directors are Denis Fitzgerald (marketing and sales) and Donald Fisher (production).



***Scanners,** d.f. loops and communications aerials surmount the new Marconi House, Hull. Below is a view of the test and repair sections of this Marconi Marine service depot.*

Principles of

D'gital Computers

By D. S. WILDE, B.Sc., A.M.I.E.E., Grad.Inst.P.

I.—BASIC REQUIREMENTS OF A COMPUTING MACHINE

THE history of digital computation is very well covered in many books and it is sufficient to highlight only a limited number of developments which have had an appreciable effect on the evolution of calculating machines.

The first mechanical aid to computation was the abacus or counting frame. It is believed to have been in use for centuries in the Far East before its introduction to Europe about 1,000 years ago. Its origins are obscure but it is in use at present, particularly in Japan, where skilled operators can beat equally-skilled operators at desk machines to the correct answers.

In 1642 Pascal invented the first calculating machine, which performed simple addition. It was widely demonstrated but never exploited. In 1673 a second machine was designed by Leibnitz with a mechanism, based on the stepped wheel, which allowed multiplication to be performed. This machine was also widely demonstrated and again was never developed. The technological advances of the industrial revolution made the production of small mechanical parts realizable and Pascal's and Leibnitz's machines have "reappeared" in the modern desk calculators of to-day.

The desk machine is a mechanical aid to computation and the intervention of a human being is essential at every step of its operation. It was Charles Babbage[1, 2] who realized that human intervention could be dispensed with and that a machine could be constructed which would automatically perform an entire computation—even printing out the answers. Initially, of course, the machine had to be provided with the input numbers and the sequence of manipulations that must be performed on them to yield the final answers.

Babbage's Fundamental Discoveries

Babbage's interest in computers was aroused as a result of the extensive work going on in the preparation of navigational and mathematical tables. The work involved in calculating these tables was prodigious and monotonous, and errors were frequent and occasionally disastrous. Babbage's first machine was conceived with this sort of application in mind but he was very soon intrigued by the possibilities of a far more ambitious machine on which almost any type of problem could be dealt with. This machine was never built, although some parts of it exist. Failure to build the machine does not detract from the significance of the ideas and principles established by Babbage. There are at least three points of fundamental importance on which Babbage showed remarkable foresight:—

(1) The human factor is prone to error when doing repetitive and monotonous work; it must therefore be dispensed with as far as possible. Babbage showed that a machine was realizable which could automatically complete a full computation, if it was given a programme of instructions to follow and a set of numbers with which to deal. Even the final answers should be printed automatically, thus removing human error in copying.

(2) The numbers and instructions must be presented to the machine in a physical form which it can recognize and manipulate. The numbers in Babbage's proposed machine were stored on gear wheels and the instructions were punched on cards similar to those used on a Jacquard loom card. Babbage decided that if a set of holes punched on a card could control the machinery which wove extraordinarily complex textile patterns, it could equally well control a calculating machine. He thus arrived at the Hollerith card which is to-day an extremely important input-output medium for digital computers, even though not used in quite the same way as Babbage used the Jacquard card.

(3) It is obvious that the machine must be able to perform all the typical arithmetical operations of addition, subtraction, multiplication and division; it is not so obvious, but quite as important, that the machine must have a "decision" facility to enable it to take one of (generally) two lines of action. This point will be taken up later.

More Recent Theory and Practice

No one immediately after Babbage followed up his pioneering work, though its importance was realized by some of his contemporaries and the succeeding years were notable for the development of desk machines and the invention of the Hollerith card with its application to accounting machines. Dr. L. J. Comrie of the Nautical Almanac Office did, however, exploit punched-card machinery in quite striking fashion for the production of astronomical tables, and his work had an appreciable stimulus on digital computing. Important theoretical work was done by Dr. A. M. Turing of the N.P.L., but it was not until the 1939-45 war that practical automatic computers were built.

Babbage's computer was purely mechanical. Had it been completed it would have been a prodigious feat of engineering, extremely expensive, and slow in operation. Electromechanical techniques were exploited for a short time in early machines and a significant and often overlooked example of a very successful computing system (whatever the punter may think) is the Racecourse Totalisator. The Harvard Mk. I computer was the first full-scale computer to be built using electromechanical devices.

The first all-electronic machine was the ENIAC (Electronic Numerical Integrator and Calculator) which used 18,000 valves. I.B.M. built a second enormous machine (the Selective Sequence Electronic Calculator) and both this and the ENIAC performed a large volume of useful calculation. If they did nothing else they did show that automatic machines were extraordinarily useful scientific and technical tools and that their potentialities were enormous.

In 1947 and 1949 Prof. J. von Neumann and his team of co-workers at the Institute of Advanced Study, Princeton, published reports of theoretical studies into the logical design of digital computers. The immediate consequences of this work were the construction of the EDSAC (Electronic Delayed Storage Automatic Computer) at Cambridge, the Manchester University machine, the ACE (Automatic Calculating Engine) at the N.P.L. and the EDVAC (Electronic Discrete Variable Automatic Computer) in the United States. Since then the pace of development has been steadily increasing.

Von Neumann's contributions to digital computing were extremely far reaching, although they do not probably appear so in retrospect and when stated baldly. Essentially they were as follows:—

(1) The recognition that the binary scale of numbers is the best to use in a digital computer.

(2) The fact that a number in the machine may be used in two quite distinct ways. It can be used purely as a number or as a code representation of an instruction. The mathematical manipulations of instructions (in number form) can be used to modify existing instructions and give great economy and flexibility.

Thus we have from Babbage and von Neumann the essential principles of all modern automatic digital computers. The rest of this article will be devoted to describing a very simple computer utilizing these principles and indicating how the component parts are realized in practical terms.

Manual and Machine Computation

Fig. 1 shows a block diagram of how a mathematician obtains solutions to a set of his equations using a desk machine and an operator to manipulate it. The equations may be extremely complicated in form and they will be broken down into a set of operational instructions (the programme), together with a list of numbers for substitution. The programme is obeyed by the operator, step by step, until the final answers are produced. The preparation of the programme is generally an extremely involved process for the mathematical equations must be transformed into operations which the machine can perform. It seems rather obvious to point out that one cannot require a differentiation operation to be performed if there is no such facility on the machine. This transformation process—numerical analysis—is an extremely important part of digital computing and its techniques are very highly developed[3].

But to return to the desk machine and its operator, it is apparent that the latter need only be an automaton capable of obeying instructions. The desk machine operator need not use any original thoughts at all but is required only to have the ability to obey a set of simple instructions.

In Fig. 2 the various sections of Fig. 1 are replaced schematically by sections of an elementary computer. The list of numbers and instructions are replaced by stores. The operator is replaced by the control unit and the desk machine is now the arithmetic unit. The computer will consist of a collection of electrical devices and there must be a translation between mathematician's language (written symbols on paper) and machine language (electrical pulses). This is provided by the input and output equipment and is extra to the original analogy in Fig. 1. Information is fed into the

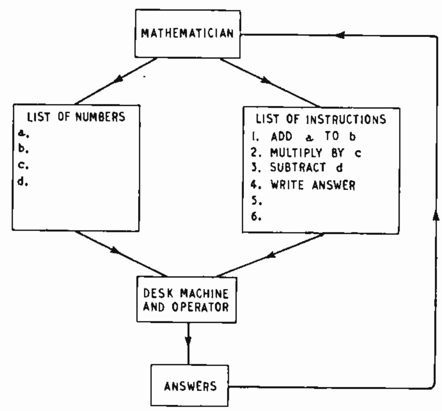


Fig. 1. Block diagram of how a mathematician solves a set of equations by using a desk machine and an operator to manipulate it.

machine using punched cards, punched tape or magnetic tape. At the conclusion of a programme, answers may be printed out or punched in coded form on cards or tape, or possibly stored on magnetic tape to be used in a later programme. However, input and output is quite a subject in itself, so its details will be ignored and its existence will be assumed to provide information to the computer in the appropriate form.

We are accustomed to dealing with numbers in the decimal system (radix 10), but even so the Anglo-Saxons are taught to deal with the most frightening variations in radix (five and a half yards are one rod, pole, or perch; fourteen pounds are one stone, and so on). This at least should show that there is nothing sacred about 10 and in fact the sole convenience of 10 as a radix for arithmetical purposes lies in it being the number of digits on a man's hands. Other radices have been tried and other number systems. The Roman system is an example of the most unwieldy. Whatever virtues 10 may have as a base for numbers it is quite unsuitable for digital computers[4]. Von Neumann advocated the scale of two and almost all large computers are binary machines in some form or other. There are various reasons for this:—

(1) In an electronic computer many of the elements are two-state devices: valves are conducting or non-conducting, relays are open or closed, capacitors are charged positively or negatively, magnetic components can have fields set up in opposite directions, and so on.

(2) It can be shown quite easily that a computer using the scale of two is almost the most economical that can be built in practice. (Actually

on theoretical grounds radix e is the most economical and radix 3 is slightly better than radix 2.)

(3) Binary arithmetic can be very easily reduced to logical (or Boolean) operations. The basic logical operations are easily realized by elementary electronic circuits—this will be shown later.

Binary arithmetic itself presents no difficulties, as long as one can count up to two, and the rules are quite unchanged.

In our use of the decimal notation the symbols 4306 really mean $4\times10^3+3\times10^2+0\times10^1+6\times10^0$. Correspondingly in binary notation the symbols 10101 really mean $1\times2^4+0\times2^3+1\times2^2+0\times2^1+1\times2^0$ which, in decimals, is equal to 21.

Addition and subtraction in binary are quite easy; a carry is developed for each pair of ones added, thus

```
  101
+  11
 ----
 1000
```

Subtracting the same pair of numbers

```
  101
-  11
 ----
  010
```

Binary multiplication has the useful quality that the multiplicand is merely repeated whenever a 1 occurs in the multiplier. It undergoes no change save for a shift in position. This has considerable circuit advantages. The final product is arrived at by addition of the partial products formed by this shifting process.

```
  101
  101
 ----
  101
 000
101
-----
11001
```

Negative binary numbers are generally recognized by a sign digit. This is a 1 in the most significant position. For example 1111 represents -1 and is interpreted as $-1\times2^3+1\times2^2+1\times2^1+1\times2^0$. This is analogous to subtracting 1 from 0 in decimal notation and arriving at 999, etc.

There are four arithmetical operations: addition, subtraction, multiplication and division. In fact only subtraction is fundamental. If one can perform subtraction then addition follows since $(a+b)=(a-(-b))$. Multiplication can be reduced to continual addition and division is continued subtraction. The only really essential arithmetic component of a computer is therefore a subtracter. Continued subtractions or additions would consume a heavily disproportionate amount of time and consequently full-size computers have built-in adders, complementers (for subtraction) and multipliers; some have dividers, and the provision of these units is generally based on some compromise.

The information given to the computer (instructions and numbers) is passed to it by the input equipment and it must be stored[5] until needed for use. The store must have a binary property, it must be compact and have the highest possible binary-digit capacity per unit-volume. Moreover, it should have the property of immediate access, i.e. any required number or instruction must be available at the instant it is needed by the programme. Other desirable properties are that the store should be able to retain information when the power supplies are switched off, and that the process of reading the information from the store does not destroy it.

Storage devices have been (and are) the part of the computer which have received the most attention and development. Modern developments are exploring extremes of physical phenomena and the prospects are quite fascinating. It is beyond the scope of this article to venture into these realms, but most computers have had their form dictated to a very large measure by the nature of their storage, and it is interesting to recount some of the early forms of storage.

The first successful store (used in EDSAC and ACE) was the mercury delay line. This takes the form of a long tube filled with mercury and fitted with a quartz crystal at each end. Electrical pulses are applied to the transmitting crystal and are turned into longitudinal acoustic pulses which travel with the speed of sound to the receiving crystal where reconversion to electrical pulses takes place. The emergent electrical pulses are amplified, shaped and reapplied to the transmitter crystal so that a recirculating store is realized.

Other stores using acoustic delays set up torsional or longitudinal vibrations in a nickel rod or wire by magnetostrictive means. There are a lot of snags with such a store. For example, once a particular group of pulses has left the transmitter it is completely inaccessible until it has reached the receiver. Temperature stability must be maintained and tubes

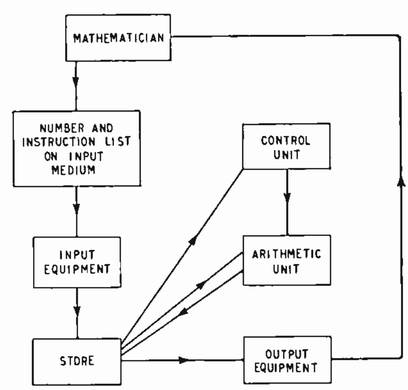


Fig. 2. In this figure the various sections of Fig. 1 have been replaced schematically by sections of an elementary computer.

full of mercury are awkward to handle as well as being bulky. Moreover, loss of power supply loses the information stored.

A store developed by Professor F. C. Williams and Dr. T. Kilburn of Manchester University used a pattern of charged spots on the screen of a cathode-ray tube to give an electrostatic store[6, 7]. This store had the advantage of immediate access since the timebase of a cathode-ray tube can be moved to any selected position instantaneously. It was not a permanent store since, obviously, loss of power supplies meant loss of stored information, nor did it retain the information on read-out, although this failing was quite ingeniously overcome to all practical purposes.

A third type of storage which is almost universal in present computers is the ferrite core store. The principle is based on the magnetic properties of small ferrite rings. The flux in the ring can be induced in either one of two directions, storing a binary 1 or 0. An excellent description of a ferrite core store has appeared in a past issue of *Wireless World*[8], so it will suffice to remark that ferrite stores have properties of immediate access and permanence. They are a compact form of store but essentially have "destructive" read-out. Despite many ventures into other forms of storage the ferrite core store still holds the field quite firmly and will probably continue to do so for several years in improved forms.

The three types of storage do not possess a very high storage capacity in terms of digits per cubic inch, and the cost in pence per digit is high. These reasons have been responsible for the provision of "backing-up" stores purely to supply information to the other stores faster than input machinery could during the actual operation of a programme. These stores have nearly always been magnetic drums consisting of a rotating cylinder coated with a magnetic oxide or nickel plated. The recording and replay is precisely that employed on digital recording on magnetic tape (out of contact) and typically over half a million digits can be stored on such a drum as opposed to only 13,000 in a complete c.r.t. electrostatic store.

Magnetic tape is being used increasingly for backing-up storage (it is the sole medium for this type of storage on the EMIDEC 2400 machine) whilst an American computer uses magnetically coated discs selected on the "jukebox" principle.

(*To be concluded*)

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ELECTRONIC CONTROL OF ROAD VEHICLES

IN a lecture given at the U.K. Road Research Laboratory, Langley, Bucks., L. E. Flory of the R.C.A. Laboratories in America described some of the work done on electronic control of road vehicles on the other side of the Atlantic. The ultimate aim is the removal of the human element as a cause of accidents on the roads.

Electronics can be employed to warn a driver of the state of traffic ahead, particularly in conditions of poor visibility and, if necessary, take over complete control of a vehicle if the driver fails to take appropriate action in time.

Two of the basic requirements described were guidance of vehicles along a "lane" on the highway and warning of the presence of a vehicle ahead. The former was effected on an experimental section of road by burying a cable along the centre of the traffic lane, feeding into it a h.f. signal and equipping the car with pick-up "aerials" on near and off sides. When the signals picked up by the two aerials are equal the vehicle is centred over the cable, while with unequal signals the "error" can be made to illuminate an appropriate deviation light, or, if servo control of steering were employed, could automatically bring the vehicle back over the guide cable. Of course suitable equipment must be fitted in all vehicles, but by the use of transistors this need not be bulky. Where two or more traffic lanes exist each can be fed with an identifying signal.

Telephonic information can be superimposed on the guidance signal giving drivers warning of approach to bends, cross-roads or any information contributing to highway safety.

For the prevention of collision with vehicles ahead travelling in the same direction loops of wire about the size of a car and spaced a few feet apart, were embedded in the roadway. The mass of metal in any vehicle passing over a loop alters its inductance and this change can be detected by electronic equipment located alongside the roadway. Electrical voltages can be generated whenever a car passes over a buried loop and these voltages fed back to preceding loops in the system, thus giving warning to following drivers with suitably equipped cars of vehicles ahead. The actual distance of the vehicle ahead can be conveyed by attenuating the signal fed to each preceding loop.

It will not overstress the imagination to visualize complete automatic control of road vehicles by extension of such systems as those briefly described here.

Industrial Groups

THE second family to be dealt with in our survey of industrial groups is that of which Jules Thorn is patriarch. Thorn Electrical Industries, which made a net group profit in 1959-1960 of £1.5M, recently acquired the Brimar cathode-ray tube and valve section of Standard Telephones & Cables and have formed a new company, Brimar Electronics Ltd., which brings the group's total to 35. Trade names of domestic sound and television equipment produced in the group's 19 establishments in this country include Ferguson, Champion, Avantic, Philco, "His Master's Voice" and "Marconiphone." Sets bearing the last two names, which are respectively the trade marks of the Gramophone Company and the Marconiphone Company, are manufactured by the Thorn group under an agreement with E.M.I.

The Thorn group had its foundation in the small company which Jules Thorn started in 1928 to manufacture and market electrical equipment. In the following list of companies within the group, those in the world of wireless head the list.

Thorn Electrical Industries Ltd.
Beam-Echo Ltd.
British Radio Corporation Ltd.
Champion Electric Corporation (C.R.V.T.C. Ltd.).
Ferguson Radio Corporation Ltd.
Nash & Thompson Ltd.
Philco (Great Britain) Ltd.
Philco (Overseas) Ltd.
Sylvania-Thorn Colour Television Laboratories Ltd.
African Lamps Pty. Ltd.
Atlas-Licht G.m.b.H. (Germany).
Atlas Lighting Ltd.
Austin Clarke (London) Ltd.
Ekco-Ensign Electric Ltd.
Elgar Research Laboratories Ltd.
Ensign Lamps (Australia) Pty.
Evansville Cabinet Co. Ltd.
George Forrest & Son Ltd.
H. Herrmann Ltd.
Industria Lampade Elettriche S.A.
Lamp Presscaps Ltd.
Manifold Machinery Co. Ltd.
F. H. Marshall & Co. Ltd.
Newhaven Cabinet Works Ltd.
Smart & Brown (Engineers) Ltd.
Talent European Co. Ltd.
Talent Furniture Ltd.
Thorn Electrical Industries (Australia) Pty. Ltd.
Thorn Electrical Industries (New Zealand) Ltd.
Thorn Electrical Industries (South Africa) Pty. Ltd.
Thorn Elektro Industrie A.G
Tricity Cookers Ltd.
Tricity Electric Ltd.
Tricity Finance Corporation Ltd.
Tricity Property Co. Ltd.

AMATEUR RADIO PROGRESS

By

J. P. HAWKER*

A REVIEW OF MODERN TECHNIQUES

ALMOST ten years ago, in these columns, the writer described[1] some of the technical trends in post-war British amateur transmitting stations. With the marking off of yet another decade in the long story of this interesting hobby (amateur transmitting licences have been officially issued in the United Kingdom for more than 50 years) a fresh survey of some modern amateur practices and trends of development may be of interest.

Amateur Activity.—During the early 1950s, amateur radio activities showed some slight tendency to decline from the high immediate post-war peak. This was partly because of the general deterioration in high-frequency propagation conditions associated with the sunspot minimum of 1954 but mainly, it is felt, because of the difficulties experienced in the prevention of interference to television reception in the immediate vicinity of the transmitter. By the mid-fifties, however, a good deal had been learnt by amateur designers about the practical reduction of harmonic radiation, while the gradual change to higher intermediate frequencies for television receivers made it simpler to avoid causing interference by i.f. break-through of strong signals. With modern transmitter technique it is usually possible—although not always easy—to avoid causing any interference, at least in areas where there is a reasonable television signal. Modern anti-television interference technique is less concerned with preventing the harmonics from being generated than with keeping them from being radiated outside the transmitter: in h.f. practice this is done primarily by enclosing all r.f. equipment in adequate screening cabinets, filtering all leads emerging from the cabinet by decoupling them to chassis, and by including a low-pass filter designed to attenuate sharply all signals above 30Mc/s in the r.f. output line (see Fig. 1).

As sunspot numbers increased from 1955 onwards, so did amateur activity. There are now in the United Kingdom some 8,500 amateur "sound" licences, plus some 850 authorizations for working "mobile" from cars and over 90 licences for television transmission. This compares with some 7,500 licences in force ten years earlier. The increase, though substantial, is less spectacular than in the United States where there are today over 200,000 radio amateurs, roughly double the figure ten years ago and an increase of 285% during the post-war period. This difference in growth rates may be partly due to the introduction in the "States" of two new classes of amateur licence: the "technician" licence, restricted to v.h.f., and the "novice" licence which provides restricted operating privileges for 12 months. Neither of these categories require the passing of the Morse test which, in the United States, is at 13 words per minute. In addition there are now more than 70,000 authorizations for the U.S. 29-Mc/s "Citizens' Band."

In the United Kingdom more realistic licence conditions were introduced in 1954 and subsequently the probationary year of "telegraphy only" with a maximum of 25 watts input (compared with the normal British limit of 150 watts) was abolished. No official steps have been taken to encourage new recruits (apart from the continuous efforts of such organizations as the Radio Society of Great Britain) and it is very noticeable how many more teenagers there are among American amateurs. In one respect there has been a tightening up of British licensing procedure: no exceptions are now granted from the

* Amateur transmitting station G3VA

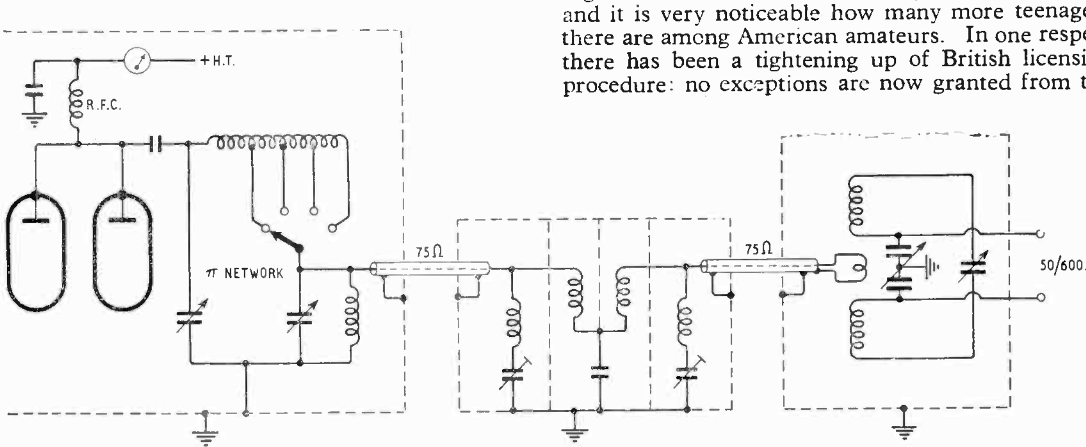


Fig. 1. Typical anti-TVI (television interference) precautions to prevent the radiation of transmitter harmonics. Harmonic signals are reduced first by the pi-network output circuit, then by the low-pass filter, and finally by the aerial tuning unit.

radio amateurs examination or, except for television, the G.P.O.-conducted Morse test.

"Table-top" Transmitters.—A notable feature of amateur transmitter construction has been the general reduction in size: the six-foot G.P.O. racks, popular at one time, are giving way to compact band-switched transmitters in which the entire equipment—including the r.f. oscillator, frequency multipliers and power amplifier, a.f. amplifier and modulator; and all power supplies—is often squeezed into one fairly substantial instrument-type cabinet. Apart from the saving in space, the main benefit bestowed by this form of construction is that the screening needed to prevent harmonic radiation is more easily applied to a single cabinet than to a number of separate units and their interconnecting cables. This trend has been encouraged by the appearance on the market of a number of factory-built transmitters and kits based on this system; it has been made possible by the availability of miniature valves and components suitable for the early stages of the transmitter and modulator.

The modern amateur transmitter normally comprises a variable-frequency oscillator, designed mainly with the requirements of frequency stability in mind and operating in the lowest frequency band for which the transmitter is intended (usually 3.5 Mc/s), followed by bandswitched frequency-multiplying stages providing outputs on 7, 14, 21 and 28Mc/s to a class-C power amplifier. This final amplifier often uses an 807 or the newer 6146 (QV06-20) valve, or two of these in parallel. Alternatively, a single 813 may be used, although it seems likely that gradually this type will be largely superseded by the recent G.E.C. type TT21 or TT22 (r.f. versions of the KT88), as these can be operated at up to the full 150-watts input with relatively low h.t. and with a more economical heater supply. The vast majority of amateur transmitters now use a pi-network to match the valve output impedance to a low-impedance coaxial output line; this provides some 30dB of harmonic suppression provided that it "sees" a purely resistive low-impedance load.

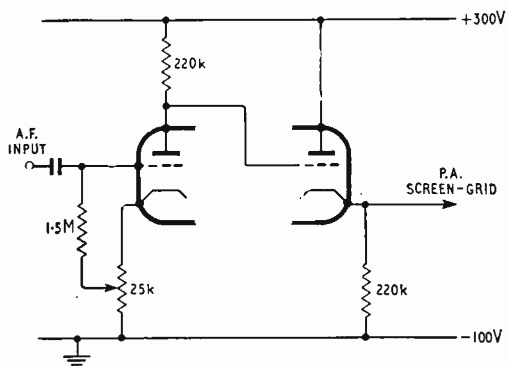


Fig. 2. Basic series gate modulator for use with tetrode power amplifier.

A 150-watt transmitter requires some 75-watts of a.f. output for high-level amplitude modulation, and this is often obtained from a push-pull modulator using such valves as 807, EL34, KT88 or TT21. Alternative a.m. systems requiring much less a.f. power, but of less efficiency, are also fairly popular, especially where the transmitter is mainly intended for telegraphy operation. One new form of screen-grid modulation which has attracted attention recently is the "series-gate" system.[2] The basic circuit is shown in Fig. 2.

Suppressed Carrier Transmission.—A major talking point among radio amateurs recently has been the growing interest in suppressed-carrier modes of telephony transmission. Although under 10% of active amateurs has so far gone over to single-sideband (s.s.b., A3a), it is now generally recognized that, especially for long distance work, or where only restricted power is available (for example in mobile work), substantial benefits are bestowed by its more efficient use of "talk power." An s.s.b. "system benefit" of 9dB is sometimes claimed in comparison with conventional amplitude modulation, though this figure assumes that full advantage is taken at the receiver of the narrower bandwidth and does not take into account the slightly lower efficiency of a linear r.f. amplifier. Apart from the power gain, s.s.b. allows many more stations to operate without mutual interference in a given band of frequences, minimizes heterodyne interference and makes it easier to operate with full voice break-in (VOX) systems. The elimination of the high-power modulator provides an economic advantage above a certain power level, though below this conventional a.m. scores financially on the grounds of simplicity.

Two main methods of s.s.b. generation are used by amateur transmitters—the filter and the phasing systems—though there is interest in other arrangements such as "the third method."[3]

Amateur Filter Systems.—Fig. 3 shows the basic arrangement of a popular filter system, though there are many variations in use. A crystal-controlled oscillator on about 465kc/s is fed, together with a low-level a.f. signal, to a balanced-modulator stage using valves or crystal diodes. A typical balanced modulator comprises a pair of similar valves with r.f. applied to the signal grids in parallel and a.f. injected in push-pull to the cathodes or screen-grids, the anodes being connected in push-pull (alternatively the modulator may have grids in push-pull and anodes in parallel). When correctly balanced, the carrier frequency is suppressed but both sets of sidebands appear in the output. The output from the balanced modulator is then passed through a tuned filter of sufficiently high selectivity to accept one set of sidebands but reject the other: such selectivity cannot normally be attained at frequencies of this order with normal inductors. In practice either quartz-crystal networks or mechanical filters are used: these filters resemble those described later in connection with receivers but often using up to six or eight crystals.

In a few factory-built designs crystal networks have been used at much higher frequencies (up to about 5Mc/s) but relatively few amateur constructors have used this technique.

After the signal has passed through the filter it emerges as s.s.b. but must be converted to the required amateur band and amplified. Since it is impossible to pass the s.s.b. signal through a non-linear amplifier, such as a class-C frequency multiplier, without introducing extreme distortion, frequency conversion is carried out in one or more mixer stages. The use of a mixer stage also makes it possible to vary the output frequency to facilitate

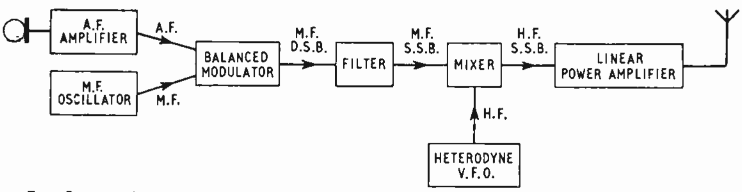


Fig. 3. Block outline of the "filter" type s.s.b. transmitter. To facilitate band switching more than one frequency conversion stage may be incorporated.

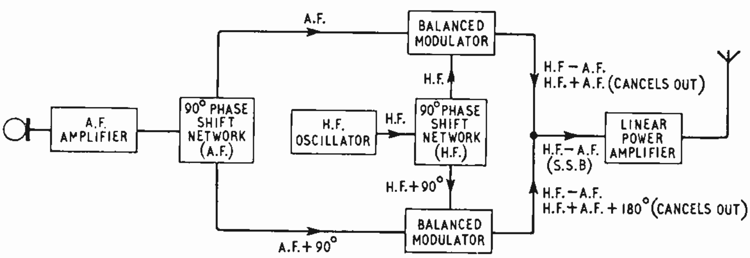


Fig. 4. The "phasing" method of s.s.b. generation applied directly to an h.f. signal. A frequency conversion stage is often incorporated to permit band changing.

changing transmitter frequency, provided that a high-stability heterodyning variable-frequency oscillator is used. Linear power amplification is usually by means of a class-B stage or a grounded-grid amplifier and calls for greater voltage regulation of the power supplies than for an A3 transmitter.

The Phasing Method.—An advantage of the phasing system of s.s.b. generation for amateur transmitters is that it functions at a much higher frequency, thus reducing the problems of frequency conversion; on the other hand, the final degree of sideband suppression is often less than with a well designed filter. This ingenious system depends upon the use of 90° phase-shift networks for both r.f. and a.f. signals: while the production of two r.f. signals 90° out of phase is not difficult, the design of a simple resistance-capacitance network which will shift by 90° a wide range of audio frequencies needs close-tolerance resistors and capacitors of unusual values. This calls for some careful checking of junk-box components before it becomes possible to obtain complete networks. A.F. and r.f. signals at low level are passed through the phase-shift networks and the outputs fed to a balanced modulator. A second balanced modulator is fed with the original signals. When the outputs from these two balanced modulators are combined it is found that both the carrier and the upper sidebands have been suppressed (see Fig. 4).

Double-sideband Transmissions.—Recently an alternative, and usually much simpler, suppressed-carrier system has enjoyed some support, particularly in the United States where it has been ably promoted by J. P. Costas (W2CRR). This is double-sideband (d.s.b.) suppressed carrier with the carrier suppressed by means of a balanced modulator (usually but not always the final amplifier stage) as shown in Fig. 5, but with no attempt made to suppress either set of sidebands. According to classical radio theory, this system requires the re-insertion of the carrier at the receiver not only at exact frequency (as in s.s.b. reception) but also in the correct phase—this would present serious difficulties. In practice, however, if the signals are received on a receiver having a bandwidth equal to that of one set of sidebands (about 3kc/s), the second set of sidebands will be automatically filtered out in i.f. stages; the signal may then be dealt with as though it were an s.s.b. emission. Suppressed-carrier double-sideband signals are thus fully "compatible" with s.s.b. transmissions, though it must be admitted that d.s.b. is not always regarded with favour by s.s.b. adherents. It does not conserve frequency space to the same extent as s.s.b. and the power gain is not great unless a special detection system is employed; on the other hand, it offers the advantage that an existing A3 transmitter can often be adapted very easily for suppressed-carrier d.s.b.

"Transceivers."—Since many of the requirements of a filter-type s.s.b. transmitter coincide with those of a good communications receiver (a highly selective filter, very stable variable-frequency oscillator, etc.) a number of factory-built "transceivers" have appeared in which many of the circuits are employed for both transmission and reception. One extremely compact equipment of this type (Collins KWM-2) intended for either fixed or mobile operation provides two-way operation on all amateur bands from 3.5 to 28Mc/s with 150 watts peak envelope power, yet it measures only $7\frac{3}{4} \times 14\frac{3}{4} \times 13\frac{1}{4}$in and weighs about 18 lb.

Communications Receivers.—The availability from "surplus" disposals of such high grade receivers as the American AR88, HRO, SX28, "Super-pro," BC312 and BC348 and the British B28 (Marconi CR100) tended for some years to inhibit the design and construction of receivers by amateurs. Recently, however, the position has begun to change, though home-built receivers are still very much in the minority. War-time designs are seldom capable of giving optimum performance on s.s.b. signals (for which they were never intended) or of providing

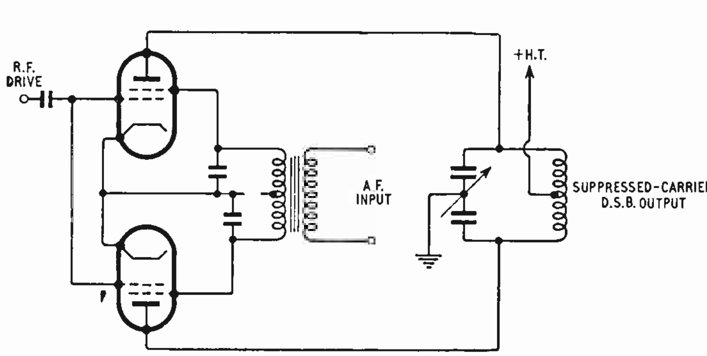
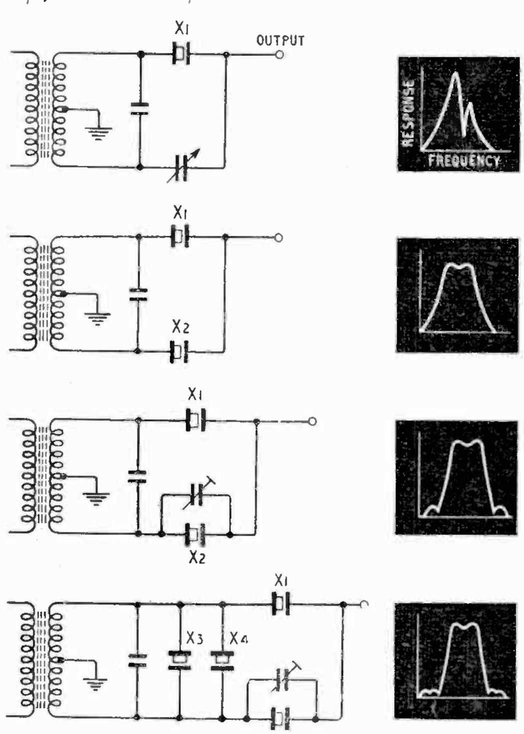


Fig. 5. Screen-grid balanced modulator for d.s.b transmission. In this circuit the grids are in parallel, while the screen-grids and anodes are in push-pull.

maximum usable sensitivity on the 21- and 28-Mc/s bands. Many amateurs have carried out fairly drastic modifications to these good but out-dated receivers: for example, rebuilding the front-ends to fit modern low-noise valves or fitting a half-lattice crystal filter to improve selectivity. Others, in steadily increasing numbers, are starting afresh and tackling the complete construction of receivers capable of providing the very slow tuning rates, the high stability and good "skirt" selectivity (response at 60dB down) needed for good s.s.b. performance. A receiver which is satisfactory on s.s.b. signals will usually be equally effective for telegraphy and A3 telephony. An experienced constructor is at present able to build a high-performance receiver at appreciably lower cost than he would have to pay for an equivalent factory-built set.

Tuning and Stability.—Whereas, even on a highly-selective receiver, an a.m. (A3) signal can usually be mistuned by several kilocycles per second before distortion becomes severe and a telegraphy (A1) signal will remain audible over a minimum of several hundred cycles per second, the missing carrier of an s.s.b. or d.s.b. (suppressed-carrier) transmission must be re-inserted with an accuracy of the order of about 25c/s if distortion is to be avoided. Unless a separate carrier-insertion v.f.o. is used, the receiver's h.f. oscillator, second oscillator (in a double-conversion superhet) or beat-frequency oscillator (the last-mentioned being used for carrier re-insertion) must be readily tunable to this degree of accuracy. Furthermore, should any of these oscillators drift, the transmission will soon become very distorted or unintelligible.

Fig. 6. Half-lattice crystal networks for s.s.b. receivers; indicating the improvement in skirt response when the crystals are correctly balanced or when extra crystals are used to reduce "humps." Typical crystal frequencies would be: X1 = 464.8kc/s; X2 = 466.7kc/s; X3 = 463 kc/s; X4 = 468.5kc/s



Although many older receivers can be used fairly effectively for s.s.b. reception by using the b.f.o. control for fine carrier insertion adjustment, it is now often considered desirable that an operator should be able to tune in an s.s.b. signal directly with the normal tuning control. This calls for a degree of bandspreading found in very few of the older general-coverage receivers: for example even the highly-regarded AR88 receiver has a tuning rate of some 125kc/s per turn of the tuning knob at 14Mc/s. The ideal tuning rate for s.s.b. depends upon such factors as the amount of mechanical backlash in the tuning system and the size and style of the tuning knob, but it would be generally agreed that a frequency shift of about 5kc/s, or even less, per revolution greatly simplifies the tuning of s.s.b. (and telegraphy) signals: the addition of a small handle to the tuning knob is then often required to reduce the time taken to tune from one end of an amateur band to the other!

Crystal-controlled H.F. Oscillator.—One result of the need for a low tuning rate and high stability has been the growing popularity of a tunable first i.f. used in conjunction with a crystal-controlled h.f. oscillator; each band—or segment of a wide band such as 28Mc/s—is selected by switching in a different crystal. In effect the "front end" for each band may be regarded as a broad-band, low-noise fixed tuned converter feeding a single-band (the first i.f.) tunable receiver: for home construction the receiver may in fact be built in this form, with each converter on a detachable sub-assembly. This arrangement allows, in the complete absence of any switching at h.f., accurate calibration and a fixed tuning rate on all bands.

Selectable-sideband Reception.—It is advantageous, in order to dodge adjacent-channel interference, to be able to select at will, without adjusting the main tuning control, the set of sidebands to which a highly-selective receiver is tuned. This applies equally to the reception of conventional a.m., d.s.b. and (with the co-operation of the transmitting station) s.s.b. emissions. One method of achieving this, applicable to a conventional type of double-conversion receiver, is to make it possible to vary the second oscillator, which would normally be fixed tuned, over about 5kc/s, allowing the pass band of the receiver to be readily shifted from one side of an a.m. signal to the other. Another, and increasingly popular, method is to provide a choice of two crystals for controlling the second oscillator, spaced twice the second i.f. apart. For example, if the first i.f. is 2,000kc/s and the second 470kc/s, then the crystals would be about 2,470kc/s and 1,530kc/s respectively. With the oscillator tuned below the signal at the mixer grid, the output will be inverted, thus automatically reversing the sideband to which the receiver is tuned. This system can be applied alternatively to any other fixed-tuned oscillator, including the beat-frequency oscillator although in the latter case it cannot be used on A3 signals.

I.F. Selectivity.—Most amateurs would consider that the optimum "nose" (−6dB) bandwidths would be of the order of 300c/s for telegraphy, 3kc/s for s.s.b. and d.s.b. and 3-6kc/s for a.m. telephony. Razor-sharp telegraphy selectivity of the order found

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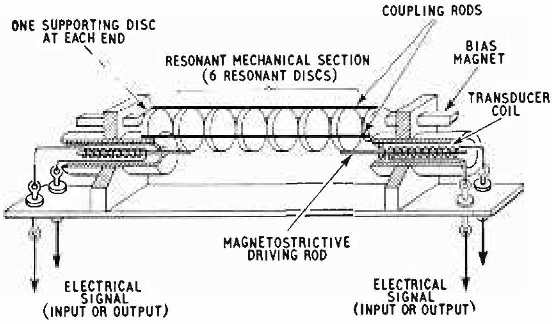


Fig. 7. The Collins mechanical filter. I.F. signals are converted into mechanical vibrations by a magneto-strictive transducer and passed along a series of resonant discs—equivalent to series resonsant electrical circuits of very high Q (about 5,000), and finally re-converted to i.f. signals by a second magneto-strictive transducer. Bandwidth of the filter is governed by the number of resonant discs and design of the coupling rods.

in some large commercial point-to-point receivers could lead to difficulty in holding some transmissions —particularly those from remote areas where poor voltage regulation tends to produce drifting signals. The "skirt" (−60dB) bandwidths should ideally be as close to the −6dB figures as possible, but in practice will seldom be less than about three times the bandwidth. As the problems of producing economically i.f. characteristics to these specifications are overcome, the secondary problem of blocking and cross-modulation by extremely strong signals outside the pass band tends to become more prominent.

Recent trends in achieving good i.f. selectivity may be summarized as follows: (1) low second (or third) i.f. of the order of 50-100kc/s in double- and triple-conversion designs; (2) two or more quartz crystals in half-lattice filter or the equivalent mechanical filter; (3) ferrite pot-cored inductors to improve Q; (4) Q-multiplier to sharpen the i.f. response, or to provide a tunable rejection notch.

The low second (or third) i.f. remains generally popular though it is noticeably absent in some of the highest-grade, factory-built receivers. One reason for this is that selectivity attained in a relatively late stage in a receiver tends to increase susceptibility to blocking and cross-modulation. One recent design[4] for home construction while using a 50-kc/s second i.f. to obtain its selectivity, included two cascaded half-lattice crystal filters at its first i.f. of 4.5Mc/s to reduce blocking.

Although the half-lattice, band-pass crystal filter was developed in the "thirties," it is only in recent years that it has really come into favour with home constructors. One reason may be that experience gained in the construction of such filters for s.s.b. transmitters has often been utilized later to improve the receiver, and the habit has spread along the amateur grapevine. The other reason (equally important) is the continued availability at a reasonable cost of surplus Type FT241 quartz crystals with suitable channel spacings. Fig. 6 shows some typical filter networks using up to four crystals.

Mechanical Filters.—The development by the American Collins Radio Company of mechanical filters (Fig. 7) has given the amateur receiver designer a new and very convenient way of obtaining a band-pass characteristic at frequencies between about 60kc/s and 600kc/s of almost any desired bandwidth with a response curve having a sensibly flat top and very steep sides. A mechanical filter can thus provide in a compact unit smaller than the average i.f. transformer, a robust filter with the characteristics of a multiple-crystal network. Such filters, however, add appreciably to the cost of a receiver and the amateur can usually construct crystal networks at lower cost—though he will be fortunate if he can obtain such carefully controlled characteristics.

Ferrite Pot Cores.—I.F. inductors of higher Q than is possible with conventional i.f. transformers can be obtained by the use of ferrite pot cores. The use of pot cores to provide a highly-selective band-pass i.f. response is described elsewhere.[5] A simpler arrangement which has been used in a number of recent American receivers and which can readily be adapted to provide variable-i.f. selectivity is the bottom-coupled i.f. transformer comprising two pot-cored inductors in separate screening compartments, all coupling being provided by the inductor C (Fig. 8).

Q-Multipliers.—The apparent Q of a tuned circuit can be increased by applying positive feedback up to the point of oscillation: this was a well-known characteristic of the reaction control on old t.r.f. receivers. Recently, this fact has been made use of in a number of devices, generally known as Q-multipliers. Usually a valve or transistor circuit at the i.f. is advanced near the threshold of oscillation and coupled to an early i.f. stage of the receiver. It has the effect of placing a high-Q circuit in parallel with the i.f. transformer. By the provision of negative feedback from a second valve stage, it is possible to convert the sharp "accept" characteristic of a Q-multiplier to that of a "reject" notch, similar to that provided by the phasing control of a single-crystal filter.

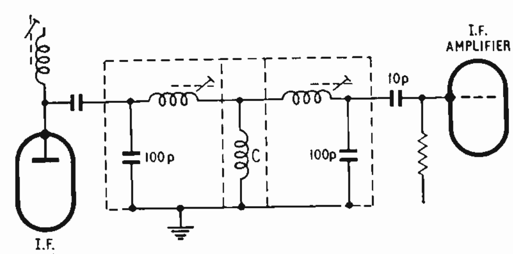


Fig. 8. Ferrite pot-cores used in a high-Q bottom-coupled i.f. transformer. Selectivity is determined by the value of C which can be altered to provide switched degrees of selectivity.

While the Q-multiplier is often added to relatively simple communications receivers to sharpen the response curve[6], the rejection notch is also quite widely used in high-performance receivers to reduce heterodyne interference from carriers operating at frequencies within the pass-band of the receiver. Fig. 9 shows the Q-multiplication effect applied to a bridged-T filter to provide an extremly sharp and deep rejection notch, as used in a well-known American receiver.

Product Detectors.—Although there is still some difference of opinion[7] as to the value, in practice, of "product detectors," these are often included in amateur receivers for use on s.s.b., d.s.b. and tele-

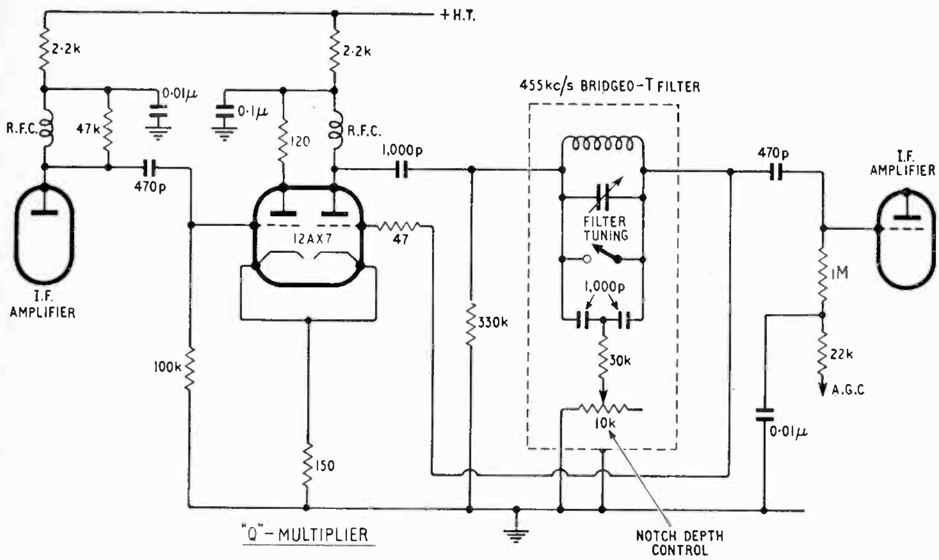


Fig. 9. The rejection notch of a bridged-T filter can be increased by Q-multiplication. The filter inductor should be of high Q construction.

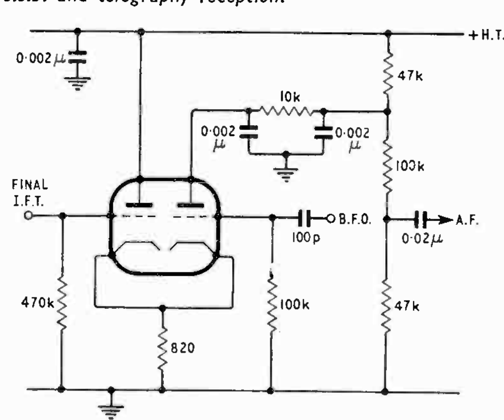
graphy signals, a diode detector being switched into circuit for A3 telephony signals. In the product detector two input signals are fed to what is basically a mixer stage: (1) the incoming signal at i.f.; and (2) the signal from the carrier-insertion or beat-frequency oscillator. The difference in frequency, after filtering out the original signals, is fed directly to the a.f. stages. Fig. 10 shows a typical circuit, using a double-triode valve, though an alternative arrangement using a 6BE6 mixer valve is also fairly widely used. The product detector reduces intermodulation distortion at low-signal levels but the claims that it facilitates s.s.b. tuning and reduces interference from a.m. stations have been challenged.

Aerials.—Although the traditional dipoles, end-fed "long-wires" and "Zepps" remain popular, many amateurs now use beam aerials either fixed or rotating for long-distance work on the 14-, 21- and 28-Mc/s bands, providing power gains of up to 10dB. The most popular arrays are adaptions from the well-known Yagi array or its folded form generally known as the cubical quad. In recent years main interest has been in the development of arrays which will function effectively on a number of different bands without the need for separate structures and transmission lines. This is usually done by the insertion of tuned traps or stubs in the aerial elements so that they will appear to the feeder as electrical dipoles on a number of different frequencies. Because a conventional horizontal polarized Yagi on say 14Mc/s is too large for many amateur locations, considerable progress has also been made in the use of loading coils, stubs or helical winding of elements to reduce their overall size without affecting too much the efficiency of the array. A multi-band array used in conjunction with a fully band-switched transmitter and receiver enables an amateur operator to change his frequency band almost without pause.

Electronic T-R Switches.—For many years it has been amateur practice to use the same aerial for transmission and reception, in order to derive maximum benefit from its directional properties. This has involved the use of a change-over switch or relay, making it difficult to operate with "listening through" (break-in) facilities and requiring some care with high power to avoid the risk of burning out the aerial input coil in the receiver. A useful family of devices, known as electronic T-R switches, has been developed to allow a single aerial to remain permanently connected to both transmitter and receiver. A low-impedance aerial feeder is taken in the usual way to the transmitter with a parallel connection to the receiver via a protective valve switch which stops any appreciable r.f. power from reaching the receiver input circuits. The switch usually comprises a sharp cut-off valve arranged so that when any r.f. power from the transmitter is applied to its untuned input circuit, grid current flows through a grid-bias resistor, thus applying bias and reducing the anode current practically to zero (Fig. 11). While the transmitter is off the valve functions as a low-level amplifier passing incoming signals to the receiver.

Mobile Operation.—A fast growing branch of amateur radio is the operation of telephony transmitters installed in cars. Some operate on all amateur bands between 1.8 and 28Mc/s, and there is also a good deal of 144-Mc/s equipment in use.

Fig. 10. One form of product detector commonly used for s.s.b. and telegraphy reception.



It is in this type of equipment that amateurs are turning gradually to transistors, primarily for a.f. amplification and modulation, but also for power conversion. Two a.f. power transistors in a push-pull inverter (Fig. 12) can provide h.t. supplies for say a 25-watt transmitter at very high efficiency and with no battery drain except when the transmitter is actually working.

Popular aerials for mobile work include inductively-loaded whip aerials on the h.f. bands and the omni-directional "halo" on 144Mc/s. The halo is a simple half-wave dipole bent round to form a circle with the ends of the element joined by insulating material: on 144Mc/s this results in a circle of about 12in diameter and enables a mechanically rigid aerial to be mounted on the roof of a car.

V.H.F. Activities.—A substantial minority of radio amateurs has always concerned itself with the investigation of v.h.f. and u.h.f. propagation and equipment. The results have not been without interest. In recent years two-way amateur contacts have been made on 144Mc/s and 220Mc/s (and one-way transmission on 420Mc/s) over the 2,540-mile path between California and Hawaii. The European 144Mc/s record is held by G5NF and I1KDB for a contact between Farnham, Surrey, and Naples, Italy; a distance of 1,084 miles. On 420Mc/s a world record was gained in 1959 by a two-way contact between G3KEQ (Sanderstead) and SM6ANR (Gothenburg, Sweden). As a special concession, certain British amateurs have been permitted to use powers up to 1kW on 144Mc/s and this has resulted in a fairly regular schedule being maintained between G2NY (near Preston, Lancs) and the Dutch Government experimental station PE1PL, a distance of 300 miles. In the microwave region, two Swiss amateurs have worked nearly 140 miles on 10,000 Mc/s, although Americans hold the record on this band with a contact over more than 185 miles.

In November, 1956, as a result of talks between the Radio Society of Great Britain and the Post Office, permission was granted—at first on a restricted basis—for the use by amateurs of the band 70.2-70.4Mc/s. This provides for the first time since the loss of the old five-metre band in 1949 a v.h.f. band on which sporadic E propagation can be expected occasionally. Although not an international allocation, the band is now available to amateurs in several countries and contacts exceeding 1,000 miles have been made.

The usual receiving set-up for long-distance v.h.f. work is to use a broad-band converter, with low-noise r.f. stage (cascode, balanced neutralized twin-triode, grounded-grid or disc-seal) and crystal-controlled oscillator/multiplier in conjunction with an h.f. communications receiver.[8] Multi-element stacked arrays, with up to about 48 elements, are used at the more elaborate stations.

V.H.F. enthusiasts took part in organized observations throughout the I.G.Y., carrying out a programme of auroral and tropospheric studies and the tracking of earth satellites. Meteor scatter communication has attracted amateur interest in the United States and Europe. On 1296Mc/s, two-way working over 2,700 miles has been achieved in the U.S. by means of "moon bounce" using 18ft and 8ft parabolic reflectors, parametric amplifiers and 1 kW klystron transmitters.

In a letter to *Wireless World* published in 1919, Marconi—in pleading for a removal of war-time

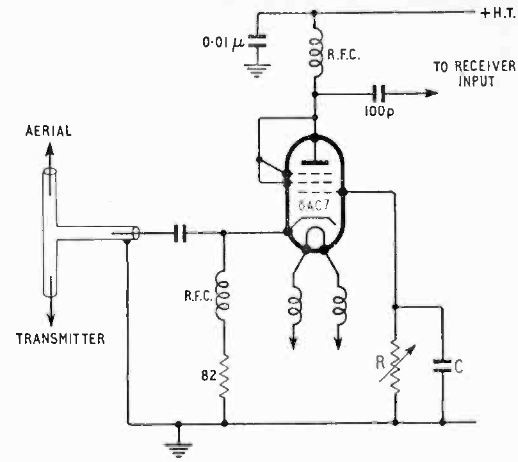


Fig. 11. An electronic T-R switch obviates the need for a transmitter/receiver aerial change-over relay, thus facilitating "break-in" operation. Values for R and C determine the recovery time of the switch and typical values are C = 0.01μF and R about 2MΩ.

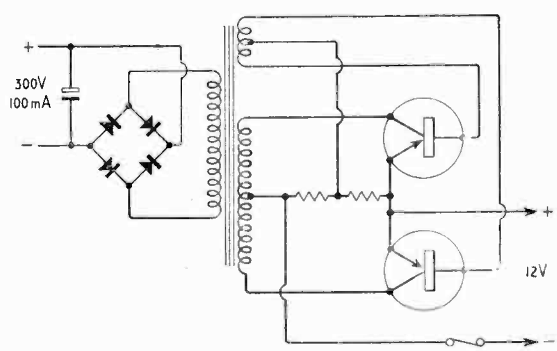


Fig. 12. Transistor d.c. converters can provide h.t. for mobile equipment at very high efficiency and with no battery drain during "stand-by" periods. Working at 1-2kc/s two junction-power transistors can readily supply some 30W or more in a push-pull circuit.

restrictions—wrote that "*a body of independent and often enthusiastic amateurs constitutes a valuable asset towards the further development of wireless telegraphy.*" More than 40 years later, who would question the continued relevance of this accurate forecast?

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NODAL ANALYSIS

By F. R. B. JONES*, A.M.Brit. I.R.E.

I.—COMPARISON WITH MESH ANALYSIS

NODAL analysis is a straightforward method of solving network problems which does not require a high standard of mathematics or electrical theory. It is complementary to mesh analysis, which we all learn as a matter of course, and its great beauty is that it is particularly suited to solving networks which contain valves and transistors. Very often, in such a case, it will yield a solution with fewer unknowns and equations, which means less work and hence less chance of error.

Scope of Network Analysis.—Before explaining nodal analysis it may be useful to the new student if some indication is given of the scope of network analysis. It is a vast and complicated subject where many of the branches call for quite a high degree of mathematical ability. This is because there are quite a number of different types of network, each of which may be excited in several different ways. (By excitation we mean the force which energises the network; it could be a steady value, supplied by a battery, a sinusoidal waveform from, say, the mains, a continuous sawtooth waveform, or even an impulse.)

With regard to networks, they may be linear or non-linear. If the former, they obey Ohm's Law within their working limits; if the latter, they don't—there may be a metal rectifier present which, when you double the voltage, does not double the current. This latter type is difficult to solve mathematically and often an approximation is made, using a series.

Again, networks may be bilateral or unilateral. A bilateral network will pass energy equally well in

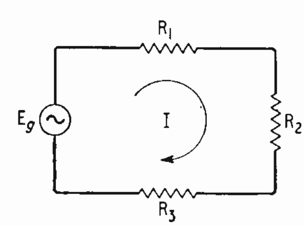


Fig. 1. Simple single-mesh network.

both directions. A unilateral network, however, will pass energy in one direction only (there may be a valve in it).

Whatever the type of network, it will have two modes of behaviour: the first known as the steady state, the second as the transient or force-free condition. The steady state is the behaviour (i.e. current flow) in the network with the driving voltage applied, after allowing the necessary time for the current to settle down to its " steady state". This is the normal working condition and the one we are generally more interested in.

The transient state exists immediately after switching on or off, it commonly lasts for only a fraction of a second, so that in most cases it may be neglected; there are times, however, when it assumes great importance.

Now we are going to confine ourselves to the study of linear networks working in the steady state: this ensures that we will not meet a current squared or cubed in our equations, which would entail the solution of a set of simultaneous quadratic or cubic equations.

In the same cunning manner we will restrict our studies to sinusoidal generators, the reason being that when a sinusoidal voltage is applied to an inductor

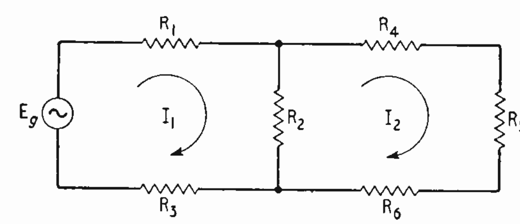


Fig. 2. Two-mesh network.

or capacitor the current is also sinusoidal, and vice versa. This is not the case with any other periodic waveform, which complicates matters when we have to use them.

Common Methods of Effecting Solutions.—The simplest circuits can easily be solved by means of Ohm's Law, which states that the current which flows in a wire is directly proportional to the voltage, provided that the temperature of the wire is maintained constant.

In a multi-mesh network (one in which there are alternative circuits for the current) it is usually best to apply Kirchhoff.

Now Kirch off propounded two laws, but as far as most people are concerned he might just as well have saved himself the effort and stuck on one, like Ohm.

His first, and universally used law is:—" The sum of the voltages around any mesh of a network is zero." This merely means that the sum of the back e.m.fs must equal the applied e.m.f., and this law is the justification for mesh analysis.

Mesh Analysis.—It may be well to revise the principles of mesh analysis so that, with memories refreshed, we can better compare it with nodal analysis, which follows. A mesh, by the way, is defined as a set of branches forming a closed path in a network, provided that if any branch is omitted from the set, the remaining branches of the set do not form a closed path.

The simplest circuit is shown in Fig. 1. Kirchhoff

*R.E.M.E. Electronic Engineering School, Arborfield.

states that the sum of the voltages across the resistors equals the applied (generator) e.m.f., i.e.

$$E_g = IR_1 + IR_2 + IR_3 = I(R_1 + R_2 + R_3)$$

It is common to assume clockwise currents as positive and anti-clockwise currents as negative and we will follow this convention.

Now consider the two-mesh network shown in Fig. 2. Kirchhoff's equation for mesh (1) will now be:—

$$E_g = R_1I_1 + R_2(I_1 - I_2) + R_3I_1$$
$$= (R_1 + R_2 + R_3)I_1 - R_2I_2$$

I_2 is subtracted from I_1 because these two currents pass through R_2 in opposite directions. Similarly for the second mesh, where there is no source of voltage, the equation becomes:—

$$(R_2 + R_4 + R_5 + R_6)I_2 - R_2I_1 = 0$$

We could write down a standard set of equations for any two-mesh network in the form:—

$$Z_{11}\,I_1 + Z_{12}\,I_2 = E_1 \text{ (mesh 1)}$$
$$Z_{21}\,I_1 + Z_{22}\,I_2 = E_2 \text{ (mesh 2)}$$

And, for the case we have just considered,

$$Z_{11} = R_1 + R_2 + R_3,\ Z_{22} = R_2 + R_4 + R_5 + R_6$$
$$Z_{12} = Z_{21} = -R_2$$

We see that Z_{11} is the impedance going round mesh (1) with mesh (2) open circuit, while Z_{22} is the impedance of mesh (2) with mesh (1) open circuit. In a bilateral network (one which does not contain a valve or similar device) $Z_{12} = Z_{21}$ and in this case both equal $-R_2$. The negative sign is due to the fact that I_1 and I_2 pass through the common coupling resistor in opposite directions.

Again, if we had a network composed of n meshes we could still write down immediately a standard set of n equations, without seeing the network. They would have the form:—

$$Z_{11}\,I_1 + Z_{12}\,I_2 \ldots Z_{1n}\,I_n = E_1 \text{ (mesh 1)}$$
$$Z_{21}\,I_1 + Z_{22}\,I_2 \ldots Z_{2n}\,I_n = E_2 \text{ (mesh 2)}$$
$$\cdots\cdots\cdots\cdots\cdots\cdots$$
$$\cdots\cdots\cdots\cdots\cdots\cdots$$
$$Z_{n1}\,I_n + Z_{n2}\,I_2 \ldots Z_{nn}\,I_n = E_n \text{ (mesh } n)$$

where $Z_{11}, Z_{22}, Z_{33} \ldots Z_{nn}$ are the impedances around meshes (1), (2), (3) . . . (n), each one measured when *all* the other meshes are open circuited. Again Z_{12} would be the impedance common to meshes (1) & (2), Z_{13} the impedance common to meshes (1) & (3) and so on, positive when the currents through are additive, and negative where the two currents are subtractive.

If you are new to network theory, check the equations for the Wheatstone bridge network shown in Fig. 3. As a matter of interest the current in the bridge resistor is 2.46 mA.

Elements of Nodal Analysis.—So far we have examined mesh analysis, which is based on Kirchhoff's First Law. We have not yet mentioned Kirchhoff's Second Law, which is very much the Cinderella of network analysis.

The second law states simply that:—"The algebraic sum of the currents at any point in a network is zero." (The current leaving a point must equal the current reaching the point.)

We notice two things about this law. One, it resembles the first law, but refers to current instead of voltage; two, it seems rather self evident since all it says is that electrons can't just disappear. Shown diagramatically in Fig. 4 we have:—

$$I_3 + I_5 - (I_1 + I_2 + I_4) = 0$$

Just as in mesh analysis we arbitrarily decided that clockwise currents were positive, so here we can decide that currents leaving the nodes (a node is a junction point) are positive and that currents entering a node are negative.

Now in mesh analysis we apply known voltages to a network and equate them against the back e.m.fs, which are all expressed as currents multiplied by impedance. Our job is to find the values of the unknown currents.

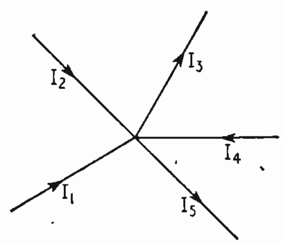


Fig. 4. (Left) illustration of Kirchhoff's second law. $I_3+I_5-(I_1+I_2+I_4)=0.$

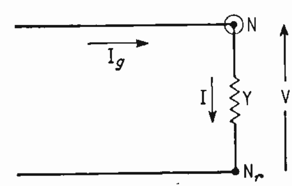
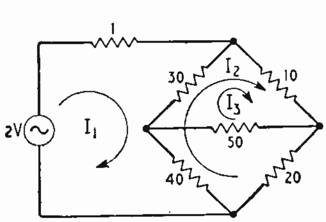


Fig. 5. (Right) simplest single-node network.



$$71I_1 - 70I_2 - 30I_3 = 2$$
$$-70I_1 + 100I_2 + 40I_3 = 0$$
$$-30I_1 + 40I_2 + 90I_3 = 0$$

Fig. 3. Wheatstone bridge circuit and its associated network equations.

In nodal analysis the reverse is the case. We are given known currents which are applied to the network, and we equate against these generator currents the other currents which flow away from the various nodes. Instead of showing these resultant currents as voltages divided by impedances, it is easier to use voltages multiplied by admittances, which is basically the same thing, since $Y = 1/Z$. Given these equations our job is now to find the unknown nodal voltages. Since voltages are measured across two points (or nodes), one node, usually earth, is selected as a reference point, and all the nodal voltages are measured with reference to this common point.

Now many students do not like admittances and shy away from using them. It is important to realize that when this is so it is only because admittances are relatively unfamiliar: they are fundamentally no harder to use than impedances, so that there is not the slightest reason to have qualms regarding them. It is only necessary to remember that whereas we add impedances in series, admittances can only be added when they are in *parallel*. Actually this makes nodal analysis easier to carry out, not harder.

Formation of Nodal Equations.—As with mesh analysis we will first examine the simplest cases.

Take Fig. 5, where a known current from an unspecified source (as yet) is fed into a single admittance Y. There will only be one voltage V, which is developed across Y, so there will be two nodes, one of which will be the reference point.

Now I_g must equal I. But I, by Ohm, must equal YV. Hence $I_g = YV$, and this is the nodal equation. If $I_g = 10$ amperes and $Y = 2$ mhos (equivalent to $\frac{1}{2}$ an ohm) then V would be 5 volts.

Consider next a "pi" network, where there will be two significant nodes and one reference node, as in Fig. 6.

At node (1) $I_g = I_1 + I_2$, and $I_1 = Y_1V_1$, as in the last example. I_2, by Ohm, will equal the voltage across Y_2 multiplied by its admittance, i.e.

$$I_2 = (V_1 - V_2)\,Y_2$$

So the complete equation for node (1) is:—

$$I_g = Y_1V_1 + Y_2(V_1 - V_2) = (Y_1 + Y_2)V_1 - Y_2V_2 \quad \text{.. (a)}$$

For node (2), $I_3 - I_2 = 0$

or $Y_3V_2 - (V_1 - V_2)\,Y_2 = 0$

giving $(Y_2 + Y_3)V_2 - Y_2V_1 = 0$ .. .. (b)

Collecting (a) and (b) we obtain the necessary set of two nodal equations:—

$$(Y_1 + Y_2)V_1 - Y_2V_2 = I_g$$
$$- Y_2\,V_1 + (Y_2 + Y_3)V_2 = 0$$

Suppose we write down a set of standard equations for a two (significant) node network, as we did for mesh analysis. They would have the form:—

$$Y_{11}V_1 + Y_{12}V_2 = I_1 \quad \text{(node 1)}$$
$$Y_{21}V_1 + Y_{22}V_2 = I_2 \quad \text{(node 2)}$$

To find what Y_{11} signifies we short node (2) to the reference point, or node. V_2 must then equal zero, so $Y_{11} = I_1/V_1$, i.e. the admittance between node (1) and the reference point, with node (2) short circuited. Referring to the "pi" network

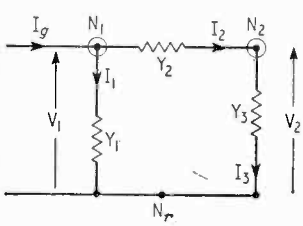


Fig. 6. Two-node "pi" network.

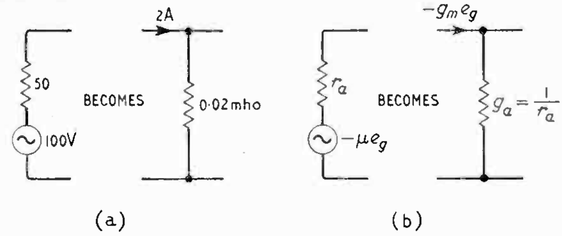
we see that the coefficient for V_1 in the first equation is $Y_1 + Y_2$, which is the admittance between N_1 & N_r when N_2 is shorted out. Similarly Y_{22} equals $Y_2 + Y_3$, which appear in parallel when N_1 is short circuited.

Y_{12}, by the same reasoning, will be the ratio of current flowing into node (1) to the voltage at node (2), when node (1) is short circuited, i.e. it is the common admittance between nodes (1) & (2), with a negative sign, because the current is flowing into the node, not out. All this fits in with the equations for the "pi" network, already found.

We can summarise in this fashion. Suppose we have an *n*-node network (neglecting the reference node) then—without seeing the network—we can write down a set of *n* nodal equations.

$$Y_{11}V_1 + Y_{12}V_2 \ldots + Y_{1n}V_n = I_1 \text{ (node 1)}$$
$$Y_{21}V_1 + Y_{22}V_2 \ldots + Y_{2n}V_n = I_2 \text{ (node 2)}$$
$$\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots$$
$$Y_{n1}V_1 + Y_{n2}V_2 \ldots + Y_{nn}V_n = I_n \text{ (node } n)$$

where Y_{11}, Y_{22} .. Y_{nn} are the individual admittances between node (1) and reference, node (2) and reference .... node (*n*) and reference, each one taken when all the other nodes are short circuited to the reference node. Y_{12} is the common admittance between nodes (1) and (2) with all nodes except node (2) short circuited, having a negative sign because the current is assumed to flow into node (1). The same applies to all the other common admittances between the different nodes.



Figs. 7(a) and (b). Two examples of the transformation of a voltage generator into its equivalent current generator.

Generators in Nodal Analysis.—The student will have noticed that in nodal analysis the generators supply known currents, whereas he is probably used to thinking of generators which supply a known voltage, like the mains. However, it is very easy, mathematically, to transform a voltage generator into a current generator by the use of Norton's Theorem. This tells us that if we short circuit the output terminals of a voltage generator, the current which flows will be the output current of the equivalent current generator. The generator impedance will have the same value after the transformation, but will appear in parallel with the supply current, instead of in series with the e.m.f. as it does in a voltage generator. In nodal analysis we show it as an admittance. The examples in Figs. 7(a) & 7(b) may help.

Summary.—Now what does all of the foregoing explanation resolve into? We can briefly list it as follows:—

1. We select the nodal points in the network and write down a set of *n* simultaneous equations, where *n* is the number of significant nodes (i.e., we exclude the reference or earth node).

2. Y_{22} is the admittance between node (2) and earth (or reference) with all other nodes short circuited; in the general case Y_{bb} is the admittance between node (*b*) and reference, with all nodes, other than node (*b*), short circuited.

3. Y_{13} is the common admittance joining nodes (1) & (3), with a negative sign, with all nodes except node (3) short circuited. Similarly Y_{bc} is the common admittance between nodes (*b*) & (*c*), with a negative sign, with all nodes except node (*c*) earthed to the reference.

4. The generators supply a set current, not voltage: the current being equal to that of the short circuited voltage generator being replaced. The current generator will have its internal impedance in parallel with its output terminals, not in series. It will be expressed as an admittance $Y_g = 1/R_g$ where R_g is the impedance of the voltage generator. On no load all the current flows through Y_g, on short circuit all flows through the short, but the magnitude of the current is always constant, irrespective of load.

That is all there is to it. You may protest that after getting used to dealing with open-circuited

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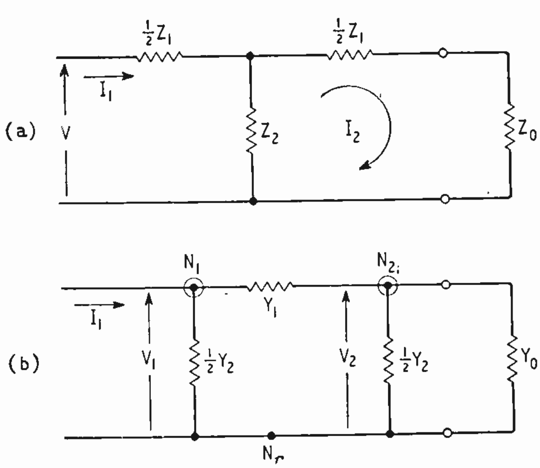


Figs. 8(a) and (b). Symmetrical "T" (a) and "pi" (b) networks terminated in their characteristic impedances.

impedances the changeover to short-circuited admittances is too much for you—a sort of "Alice through the looking glass" adventure, with a strange kind of upside down logic. For myself, I still like wandering with Alice through looking-glass land and it is surprising how many quotations from Alice grace profound mathematical tomes. It's only mental inertia which may hold you back, not the difficulty of the subject. If you wish to acquire dexterity in the mathematical solution of networks, especially those containing valves and transistors, the effort is well worth making.

So let's try some examples.

Examples.—1. Find the characteristic impedance of a symmetrical "T" and a symmetrical "pi" section.

The characteristic impedance of a network is that impedance, placed across the output terminals of the network, which gives the input impedance the same value as itself.

The "T" network (shown in Fig. 8a) has two meshes and three significant nodes. Mesh analysis is obviously better.

We write down the mesh equations:—

$$Z_{11}\, I_1 + Z_{12}\, I_2 = V \quad (a)$$
$$Z_{21}\, I_1 + Z_{22}\, I_2 = 0 \quad (b)$$

The input impedance will equal V/I_1 and this is to equal Z_0, the load.

$$\text{From (b)} \quad I_2 = -\frac{Z_{21}}{Z_{22}} I_1$$

Substituting this in (a) we get

$$Z_{11}\, I_1 - \frac{Z_{12}^2}{Z_{22}} I_1 = V$$

$$\therefore Z_{11} - \frac{Z_{12}^2}{Z_{22}} = \frac{V}{I_1} = Z_0$$

$$\text{And } Z_{11}\, Z_{22} - Z_{12}^2 = Z_0\, Z_{22}$$

From an inspection of the network we see that

$$Z_{22} = Z_{11} + Z_0$$
$$\therefore Z_{11}^2 + Z_{11}\, Z_0 - Z_{12}^2 = Z_0\, Z_{11} + Z_0^2$$
$$\therefore Z_0^2 = Z_{11}^2 - Z_{12}^2$$

Suppose $\frac{1}{2}Z_1 = 168$ ohms & $Z_2 = 987$ ohms.
Then $Z_0^2 = 1{,}155^2 - 987^2 = 360{,}000$

$$\therefore Z_0 = 600 \text{ ohms}$$

In the "pi" network (shown in Fig. 8b), we have two nodes and three meshes, so we use nodal analysis. You will see how the equations and result seem almost a mirror image (or Alice's looking-glass reflection) of the "T" network.

Our standard equations are

$$Y_{11}\, V_1 + Y_{12}\, V_2 = I_1 \ (a)$$
$$Y_{21}\, V_1 + Y_{22}\, V_2 = 0 \ (b)$$

$$\text{From (b) } V_2 = -\frac{Y_{21}}{Y_{22}} V_1$$

Substituting this in (a) we get

$$Y_{11} - \frac{Y_{12}^2}{Y_{22}} = \frac{I_1}{V_1} = Y_0$$

$$\text{And } Y_{11}\, Y_{22} - Y_{12}^2 = Y_0 Y_{22}$$
$$\text{But } Y_{22} = Y_{11} + Y_0$$
$$\therefore Y_{11}^2 + Y_{11}\, Y_0 - Y_{12}^2 = Y_0\, Y_{11} + Y_0^2$$
$$\therefore Y_0^2 = Y_{11}^2 - Y_{12}^2$$

Suppose $Z_1 = 365$ ohms & $2Z_2 = 2{,}142$ ohms. Then $Y_1 = 2.74$ millimhos, $\frac{1}{2}Y_2 = 0.468$ millimhos, $Y_{11} = 3.21$ millimhos and $Y_{12} = -2.74$ millimhos.

Then $Y_0^2 = Y_{11}^2 - Y_{12}^2$
$= (10.30 - 7.51)\ 10^{-6} = 2.79 \times 10^{-6}$
$\therefore Y_0 = 1.67$ millimhos and $Z_0 = 600$ ohms

2. Two identical tuned circuits are coupled, first mutually and then with top capacitance. Compare the effects of varying the coupling on the bandwidth of the circuits.

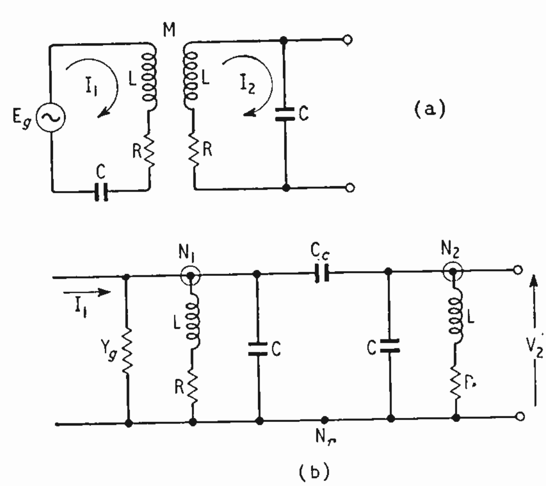
The mutually-coupled circuits are shown in Fig. 9(a). Where mutual couplings occur it is usually better to use mesh analysis. Starting with the same basic equations and proceeding in the same manner as before we reach the equation

$$I_2 = \frac{-Z_{12}\, E_g}{Z_{11}\, Z_{22} - Z_{12}^2} = \frac{-Z_{12}\, E_g}{Z_{11}^2 - Z_{12}^2}$$

Now $Z_{11} = Z_{22} = R + j\omega L + 1/j\omega C$ and $Z_{12} = j\omega M$.

Remembering that $A^2 - B^2 = (A+B)\ (A-B)$, we obtain

$$I_2 = \frac{-j\omega M E_g}{[(R+j\omega L+1/j\omega C)+j\omega M]\ [(R+j\omega L+1/j\omega C)-j\omega M]}$$
$$= \frac{-j\omega M E_g}{[R+j\omega\ (L+M)+1/j\omega C]\ [R+j\omega\ (L-M)+1/j\omega C]}$$



Figs. 9(a) and (b). Mutually- (a) and top-capacitively- (b) coupled tuned circuits.

We see that the denominator will have one minimum when $\omega_1 (L+M) = 1/\omega_1 C$ and another when $\omega_2 (L-M) = 1/\omega_2 C$, which give us the two current peaks we associate with tuned-coupled circuits (Fig. 10a). The peaks will be more or less symmetrical about the resonant frequency of one circuit when isolated from the other. Increasing the coupling M increases the bandwidth more or less symmetrically about the centre point if M/L is $< 0{\cdot}1$.

For the top-capacity coupling (Fig. 9b), we start to count the meshes but quickly decide to employ nodal analysis. In any case the generator is usually a pentode valve, which is commonly called a constant-current valve whilst we are really interested in the output voltage not current.

The standard set of nodal equations will lead us to

$$V_2 = \frac{-Y_{12} I_1}{Y_{11}{}^2 - Y_{12}{}^2}$$

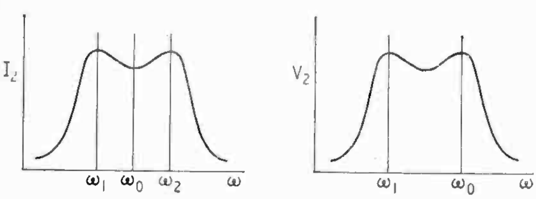
Where, if we neglect resistance,

$Y_{11} = Y_{22} = 1/j\omega L + j\omega C + j\omega C_c$ & $Y_{12} = -j\omega C_c$

Using the $A^2 - B^2$ formula again we obtain

$$V_2 = \frac{j\omega C_c I_1}{[1/j\omega L+j\omega C+j\omega C_c+j\omega C_c][1/j\omega L+j\omega C+j\omega C_c-j\omega C_c]}$$

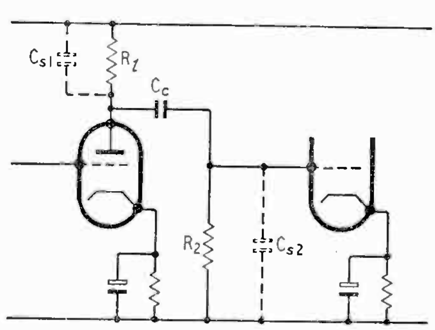
$$= \frac{j\omega C_c I_1}{[1/j\omega L+j\omega\,(C+2C_c)]\;[1/j\omega L+j\omega C]}$$

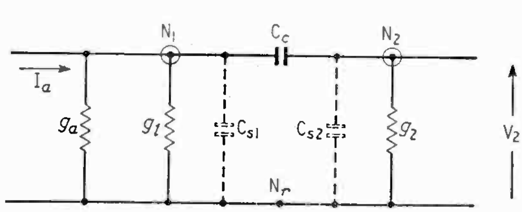


(a) (b)

Figs. 10(a) and (b). Frequency response curves of mutually- (a) and top-capacitively -(b) coupled tuned circuits of Figs. 9(a) and (b).

(a)





(b)

Figs. 11(a) and (b). Audio-frequency voltage amplifier circuit (a) and its nodal equivalent circuit (b).

The response curve is shown in Fig. 10(b). We see again that there will be two peaks, but now one of them is independent of the coupling element. Hence increasing the coupling causes the lower peak to move to a lower frequency, but the upper peak remains stationary. This type of coupling is therefore unsuitable for a variable-bandpass circuit, since increasing the coupling makes the passband asymmetrical. This asymmetry applies to all forms of coupling except the mutually inductive, and accounts for the popularity of the latter.

3. Obtain expressions for the gain of an audio-frequency voltage amplifier at low, medium and high audio frequencies.

The circuit, and its nodal equivalent, are shown in Figs. 11 (a) and (b).

At medium frequencies it is usually easy to make the effects of all the capacitances negligible. This reduces the equivalent circuit to having only one significant node, and

$$V_2 = \frac{I_a}{g_a + g_l + g_2}$$

At high frequencies the effect of the coupling condenser can again be neglected, but the stray capacitances must be considered. The equivalent circuit will only have one node as long as C_c may be neglected, so we get

$$V_2 = \frac{I_a}{(g_a + g_l + g_2) + j\omega(C_{s1} + C_{s2})}$$

At low frequencies the stray capacitances can usually be neglected, but the effect of the coupling capacitor cannot: hence we must employ the two nodes, as shown. Let g_a & $g_l = g_1$.

Then $Y_{11} = g_1 + j\omega C_c$, $Y_{22} = g_2 + j\omega C_c$ & $Y_{12} = -j\omega C_c$

Employing our basic two-node equation and substituting we get

$$V_2 = \frac{-Y_{12} I_1}{Y_{11} Y_{22} - Y_{12}{}^2}$$

$$= \frac{j\omega C_c I_a}{(g_1 + j\omega C_c)(g_2 + j\omega C_c) + \omega^2 C_c{}^2}$$

$$= \frac{j\omega C_c I_a}{g_1 g_2 + j\omega C_c (g_1 + g_2)}$$

I hope you can see how easily the three equations can be obtained from the one equivalent circuit and set of equations. In the three equations I_a may be replaced by $-g_m e_g$.

Conclusion.—Most valve equations and formulae are formed on the implicit assumption that the valve is truly unilateral, i.e. that voltages and currents in the output circuit of the valve have no effect upon the input; but sometimes this assumption is not valid, as for example, where Miller Effect is present, or when feedback is employed.

Transistors are much worse than valves in this respect, they are seldom if ever truly unilateral. This tends to make the mathematical calculations complicated and tedious. We will endeavour to show, in the second half of this article, that in this connection nodal analysis can effect considerable simplification and is much easier to use.

(To be concluded.)

LETTERS TO THE EDITOR

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

Local Sound Broadcasting

YOU say in your Editorial on Local Sound Broadcasting in the October issue that regional broadcasting as the BBC has organized it is "administratively convenient." I am not sure whether this is meant to be a compliment or a criticism, but the purpose behind the establishment of the regions is the contribution of programmes, both sound and television, to the national networks, and for each region to serve its own audience with programmes which reflect the special interests of the particular area. Certainly BBC regions are large but not too large for regional news bulletins. In most regions VHF transmitters on the Home Service wavelengths are also being used to give programmes of news and general local interest covering a smaller area than the regional news bulletins on medium waves. The BBC policy of having studios in several important centres of population in each region makes this possible.

The BBC has prepared plans for the introduction of a system of local broadcasting on VHF, taking into account the experience gained from the localized area services on VHF which have been developed within the existing BBC regions in recent years. Local broadcasting will need low-power VHF stations with single transmitters to provide local programme services, although there may be a need for supporting medium-wave transmitters in the early years. We believe that a service of local news and other programmes reflecting the interests of smaller self-contained communities will be of real value. Each local station will be free to develop its own characteristic programme in accordance with the wishes of the community it serves, and when not originating local material, the local stations will take their programmes from the main BBC networks.

The BBC has asked for the additional frequencies for this purpose. As you say, this problem is not an easy one, and moreover the success of the scheme will depend on the production of high-quality VHF receivers of all types at the right prices. Three-and-a-half million VHF receivers are already in use and our assessment is that the listening public is very satisfied with the service because of the excellent quality and the reduction in interference.

HAROLD BISHOP
Director of Engineering
London, W.1. British Broadcasting Corporation

Line Standards

I DO not know why Mr. Smye-Rumsby should, in the last paragraph of his letter published in your September issue, make the inaccurate statement that the low-frequency wired television systems do not provide a bandwidth of more than 2Mc/s. The bandwidth of these systems is well over that required for 405-line standards and can readily be extended to cater for 625 or even 819 lines if necessary. In general, the performance of these wired networks is maintained to standards which impose no limitation on the performance of the best television receivers, whether they be designed for operating from an aerial or from the wire.

R. P. GABRIEL,
London, S.W.1. Chief Engineer, Rediffusion Ltd.

IT is difficult to understand why Mr. Smye-Rumsby should make the rather sweeping statement that persons receiving their television signals via "I.F. Wired Systems" do not enjoy a bandwidth of more than 2Mc/s. Assuming that the transmission being received originally contains a full 3Mc/s bandwidth (and this is by no means always the case) the signal degradation due to the receiving and amplifying equipment in the network is negligible in all systems that I know of even at distances of some 10 miles from the receiving point. Your readers might be interested to know that a large number of families in the London area using this method of reception now receive their transmissions via direct landlines throughout from the B.B.C. and I.T.A. with consequent improvement to the high frequency response of some transmissions. This improvement is clearly visible at the viewers' installations.

K. A. RUSSELL,
British Relay Wireless and Television, Ltd.
London, E.C.1.

IN discussing television line standards, we should bear in mind that the horizontal resolution of a 625-line picture, with 5Mc/s video bandwidth, is no greater than the horizontal resolution of a 405-line picture with 3Mc/s video bandwidth. However, the concensus of opinion nowadays is that we might as well change to 625 lines eventually, if only to pacify those who persist in believing that any increase in the number of lines automatically gives an improvement in picture quality.

The Television Advisory Committee's recommendation of a 5.5Mc/s video bandwidth makes rather strange reading. Paragraph 17 of the Committee's report recalls that, in the 1957/58 Band V Field Trials, the *overall* assessment of a 21-inch 625-line picture with 5Mc/s video bandwidth was not significantly better than the overall assessment of a 405-line picture of the same size—in spite of the fact that the observers noticed the reduced visibility of the scanning lines in the 625-line picture. The report goes on to say that the Technical Sub-Committee at first took the view that a 625-line system with 6Mc/s video bandwidth would show a "definite superiority," but that they afterwards concluded that a 5.5Mc/s bandwidth could be used with "no loss in picture quality." In other words they are suggesting that a 0.5Mc/s increase in bandwidth from 5Mc/s to 5.5Mc/s would give a noticeable improvement, but that a 0.5Mc/s restriction from 6Mc/s to 5.5Mc/s would not cause any noticeable loss. Can it be that the Committee wished to avoid recommending standards which have been shown to offer no overall advantage over 405 lines, but at the same time they wished to avoid the political implications of recommending the standards which are used in Eastern Europe?

In your October issue, M. V. Heffernan suggests that, apart from the number of lines, the C.C.I.R. 625-line system is advantageous in that it uses f.m. sound and negative picture modulation. It is difficult to agree with this view, for the following reasons:

(1). The start of 625-line transmissions will be our only opportunity to lay down the best standards for a future compatible colour service. A.M. sound has been shown to have important advantages in minimizing interference with the colour picture, and positive picture modulation to have equally important advantages for the compatible monochrome picture.

(2). The one real advantage of f.m. for sound broadcasting is that it offers greater resistance to some types of interference. This is quite unimportant in television, as it is the picture signal which is always the first to be affected by interference, long before the a.m. sound—with only a quarter of the vision e.r.p.—has run into trouble.

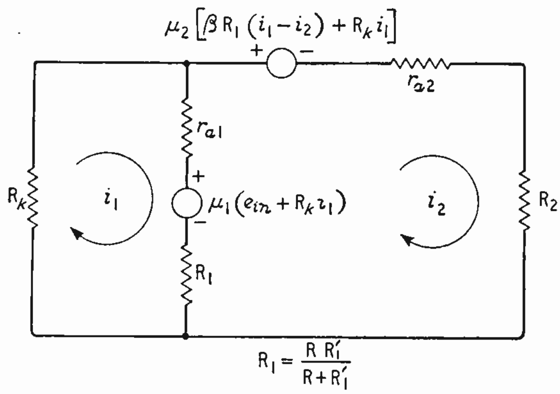
(3). Another of the findings in the Band V Field Trials Report is that synchronizing is better with positive than with negative picture modulation. As this is one of the few instances where such a comparison has been made on a statistically reliable basis, it seems reasonable to believe that this conclusion is correct.

I therefore suggest that the evidence is in favour of using a 625-line system with a.m. sound and positive picture modulation. The exact video bandwidth is comparatively unimportant, as we shall not in any case be able to use the 7 Mc/s needed for equal horizontal and vertical resolution.

London, N.W.9. CHARLES ROGERS.

Signal-flow Diagrams

I HAVE just been reading the excellent articles on signal-flow graphs by Thomas Roddam which appeared in the February and March issues. Ever since the publication of Mason's work in 1953 I have been trying to convince myself that the signal-flow graph method is quicker than conventional network analysis but have yet to find an example which yields more readily to analysis by the signal-flow graph method. In the March issue a lucid account is given of the signal flow-graph analysis of a cathode-coupled limiter and it is stated that " the original circuit, as anyone who has ever carried out the solution by algebra knows, is by no means as simple as one might expect."



From Fig. 1 of that article we have at once the linear network representation shown below. The voltage equation is

$$\begin{bmatrix} r_{a1}+R_1+R_k(1+\mu_1) & -(r_{a1}+R_1) \\ R_k(\mu_2-\mu_1)+\mu_2\beta R_1-(r_{a1}+R_1) & r_{a1}+R_1+r_{a2}+R_2-\mu_2\beta R_1 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} -1 \\ 1 \end{bmatrix} \mu_1 e_{in}$$

from which the response of the network can be obtained. In particular, for zero switching time (infinite gain), we require the determinant of the above resistance matrix to be zero. Thus

$$R_k(1+\mu_1)(r_{a2}+R_2)+(r_{a1}+R_1)[r_{a2}+R_2+R_k(1+\mu_2)]-\beta\mu_2 R_1 R_k(1+\mu_1)=0$$

exactly as obtained by putting $t_l = 1$ in Mr. Roddam's result.

Again, therefore, I fail to see what is gained by using the signal-flow graph method. These remarks, are not meant to detract from Mr. Roddam's excellent articles but I infer from them that he has convinced himself of the superiority of the method. I am wondering if there is anything he might be good enough to say that will convince me. S. R. DEARDS,

Department of Aircraft Electrical Engineering,
The College of Aeronautics.

Cranfield, Bucks.

The author replies:

Mr. S. R. Deards infers that I have convinced myself of the superiority of the signal-flow graph method, which is false, and wonders if I can convince him, which is probably impossible. An examination of the literature, however, suggests that there is an increasing number of people who find the method convenient or attractive so that, like it or not, we must understand it.

The particular problem of the cathode-coupled limiter can be handled in at least four different ways. The traditional methods, using the mesh currents and solving the resulting equations by the piece-meal elimination of unwanted unknowns, is tedious and liable to error. It is, unfortunately, the only method which many engineers can understand. Mr. Deards writes down, dare I say with a flick of the wrist, the model matrix. My own choice, based on the habit of almost a quarter of a century, is to use the Streker-Feldkeller matrix approach to avoid the need for thought. Finally we have the s.-f. graph.

I can think of no justification for the first method except the laziness of those who can look forward to a lifetime of drudgery because they will not learn to use the tools of their trade. The nodal matrix is undoubtedly the most elegant and suffers only from the disadvantage that all one's eggs are, as it were, in one matrix. My own choice has very considerable advantages when much of one's time is spent on administration and interruptions are frequent; like knitting, one can take it up or leave it alone.

The signal-flow graph, another step-by-step method, has many of the advantages of the s.-f. matrix. In addition it will throw out without extra effort the conditions at test points. I suspect, however, that its chief virtue is that many people like graphical and quasi-graphical methods, even though they merely represent modern packaging for established algebra. We must hope that users of the s.-f. graph include some engineers who would otherwise have abandoned their problems altogether. THOMAS RODDAM.

Deeper Amplitude Modulation

WITH reference to the letter from your correspondent M. Konopasek in the August issue, in which he accuses French a.m. stations of excessive sideband splatter, may I be allowed entirely to disagree with him, as far as medium waves are concerned. I also feel that his choice of the adjective "notorious" is singularly inaccurate inasmuch as the R.T.F. is meticulous in its observance of strict technical standards on medium waves.

As a resident in France for several years, I have long enjoyed excellent reception of Lisbon I (665 kc/s) without a whisper of sideband splatter from Rennes (674 kc/s); of the B.B.C. European Service (1340 kc/s) without QRM from the R.T.F. chain on 1349 kc/s; even of the Light Programme chain on 1214 kc/s, under good conditions, without excessive "splash" from the local 100-kw transmitter on 1205 kc/s. Note that there is a 9-kc/s separation between these channels. One could continue citing such examples. It is your correspondent's receiver, I think, not the R.T.F., which needs readjustment.

On the other hand, the R.T.F. 164 kc/s transmission on long wave is indeed much more deeply modulated, as several of your correspondents have indicated. This is for two reasons:—

(1) To overcome certain problems of coverage caused by the use, by day, of a relatively low-powered transmitter (250kW) and to try for a European coverage by night when power is doubled and when this station puts out programmes which are meant to be, and often are, of European interest.

(*Continued on page* 563)

(2) To overcome the QRM which is experienced, especially in Eastern France, from the famous V.o.A. transmitter on 173 kc/s (to say nothing of the jamming thereto attracted).

It is worth remarking that the sacrifice in quality which all this involves has been noticed by the average listener to the France I programme in this country, and is believed to be one of the contributory causes of the popularity here of dear old commercial Europe No. I.

In conclusion, as a listener with many years' experience of the medium-wave broadcast band, I tender the opinion that the chief "muckers-up" (the French have a much more expressive verb than this) of this band are, certainly *not* the R.T.F., but the Spaniards and the East Germans with their nasty signals scattered where they cause the maximum of interference.

Bordeaux. GERARD A. CASEY

I AM horrified at the suggestion made by your correspondent W. Blanchard (June issue) that the B.B.C. should increase modulation levels on their medium- and long-wavelength transmissions.

Really excellent quality can frequently be obtained from these using ordinary receivers, although modification of detector, a.g.c. and output stages to reduce distortion is needed in many cases.

I find the distortion caused by clipping over-modulation extremely distressing, and obvious volume compression fatiguing to the ear, and am very grateful to the B.B.C. for their careful efforts in minimizing these. These efforts might well be extended to television sound, where heavy clipping is often painfully obvious even through all programmes in a series (e.g. "Look") or in a "celebrity" concert.

No; good quality transmission should be kept available on medium and long waves at least until transistor v.h.f. portables giving good reproduction are a commonplace and distortion due to multipath reception of f.m. has been abolished. If Mr. Blanchard wishes to fit additional filtering, clipping and volume compression circuits into his car radio he can, of course, do this for himself.

Malvern, Worcs. G. F. JOHNSON.

The Genius of A. D. Blumlein

EVER since I began to take an interest in the origins of the waveform techniques that I and many other engineers use and almost take for granted, I have been learning how very many of them are due to A. D. Blumlein. I was therefore extremely interested in the article in September's issue on this great circuit engineer and in the description of his contributions to the whole field of electronics. While many of those relating to waveform manipulating circuits have passed into general use, a study of some of his patents shows that many useful techniques are still little known. For example, his patents[1, 2] on the long-term pair envisaged

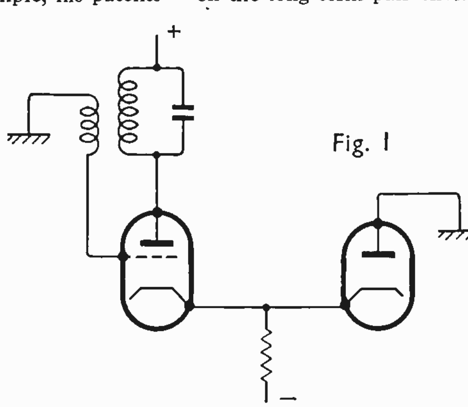


Fig. 1

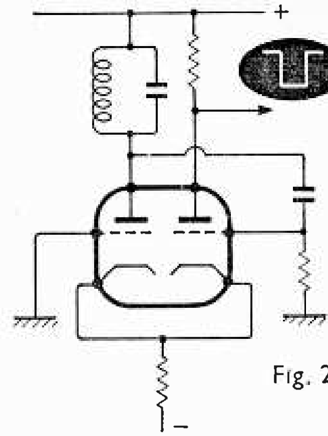


Fig. 2

much more than the use of the circuit as a phase splitter or as an amplifier with discrimination against push-push signals.

Circuits are described which use a "pair" as a "switch" actuated by the differential grid voltage. Cross-coupled neutralizing capacitors for sharpening the pulse outputs are also shown, and this application of positive feedback from the "switch" outputs to the controlling grid circuits clearly foreshadows a whole family of multivibrators, oscillators, trigger circuits and so on,[3, 4, 5] based on this circuit and which are readily "designable."

The controlled-amplitude oscillator Mr. Scroggie mentions is a good example of a designable circuit using this principle. If the circuit is redrawn, Fig. 1, for use with a negative supply line its long-tailed-pair characteristics are more obvious. If a complete pair, Fig. 2, is used the phase-reversing inductive coupling can be dispensed with,[4] and an approximately square output waveshape also obtained.

These circuits, and transistor developments of them, have many valuable features and are particularly useful in the higher audio and ultrasonic frequency range.

Newcastle-upon-Tyne. R. FOSS,
Department of Electrical Engineering,
University of Durham.

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[1] British Patent 482,740.
[2] ,, ,, 514,065.
[3] ,, ,, 535,778.
[4] ,, ,, 540,941.
[5] Newman, E. A.; Clayden, D. O.; Wright, M. H. "The Mercury Delay Line Storage System of the ACE Pilot Model Electronic Computer." *Proc. I.E.E.*, 1953, Vol. 100, Pt. 2, p. 445.

QUIZ

ITALIAN NATIONAL RADIO SHOW

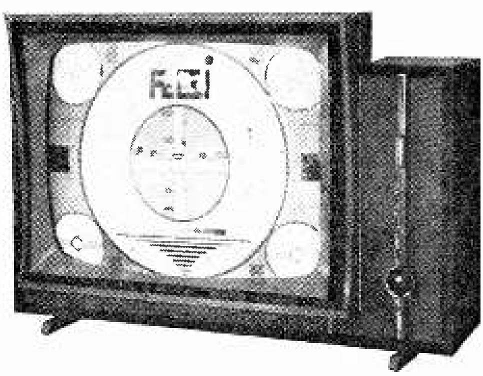
Characteristic Features of Design in Domestic Receivers

HELD at the Palazzo dello Sport, Milan, from September 10th until 19th, the 26th Italian National Radio Show included a component "salon" comprising in all nearly 200 stands. The output of the Italian industry for 1959 was worth about 100,000M lire (some £57.5M sterling), an increase in five years of 35% and the fact that in Turin—a relatively prosperous industrial community—only one family in five has a television receiver—may be taken as a pointer for future growth, although it is only fair to note that in Naples, poor by Turin's standards, one family in three has a receiver. At the moment, there is only one television programme network in Italy, using, because of the many stations, all of Bands I and III for its 625-line narrow-bandwidth service. A second service is due to start next year in Milan in the u.h.f. bands: already a few u.h.f. aerials have made their appearance on the Milan skyline.

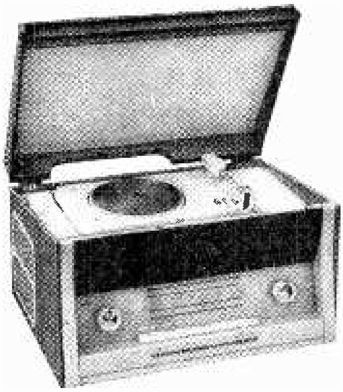
On the Radiotelevisione Italiana (R.A.I.) stand a series of panels emphasized the potentialities of sound broadcasting, giving particular reference to f.m. with which very good coverage is given by (on the last day that we visited the show!) 795 transmitters. According to these panels, 5M families do not have a radio receiver, but of these 2M are in a position to buy one "tomorrow." The R.A.I.'s 26,700 hours of home sound broadcasting in four programmes (rather similar to our Home, Light, Third and Network Three) in 1959 compares well with the B.B.C.'s 20,000 or so hours.

Perhaps the most noticeable feature of the television receivers was provision for u.h.f. reception, usually by a second tuner unit and control knob. A fair variety of u.h.f. tuners was found: in the main these use at least a crystal mixer and valve oscillator, and at most a three-valve r.f.-mixer-oscillator line up. This practice of providing circuits capable of better performance than that of the simplest possible arrangement seemed to be fairly general practice, in spite of the fact that many centres of dense population must be in transmitter "swamp" areas. For instance, the number of valves in a receiver is usually 18 to 22 explaining, no doubt, the good reproduction of pictures from the Swiss transmitter in the Ticino, without, as far as the eye could see, anything too esoteric in the way of aerials on the roof of the exhibition hall. Many of the receivers without a.f.c. (which was the rule rather than the exception on sets with motor-driven tuners for remote control) had magic-eye tuning indicators.

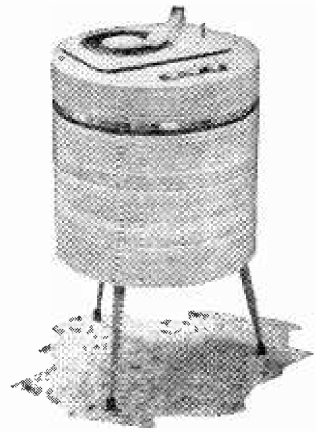
Receiver power supplies are something of a problem because in Italy many of the mains supplies are in the region of 150 or 160V—too high for convenient voltage-doubling, as is American practice with the 117-V line, and too low for direct rectification as is common in 200 to 250-V countries. In the simplest arrangement an auto-transformer is used to supply a half-wave rectifier and a series heater chain; but other forms include an "overwind" for full-wave rectification and employ parallel-connected heater circuits. Mains-voltage regula-



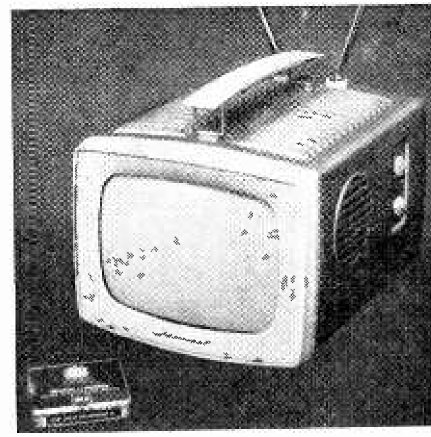
In the 23-in Voxson TV receiver (left) the c.r.t. extends just beyond the confines of the box, but familiar chassis construction is used. The Philco 19-in model (below left) has the major part of the chassis flat, in the lower part of the "box." A step further is to enclose the tube in a protective shell: the 19-in c.r.t. of the Atlantic TV-radio-gram shown (below) is raised from the cabinet by a motor drive: table models by Philco and Phonola have a flat chassis in a box below the c.r.t., whilst Atlantic have a set with the c.r.t. on top of a floor-standing pedestal.



Radio Allocchio Bacchini: small table radiogram to which legs can be fitted.



Framez "Modern Juke-Box" gramophone.



7-in portable television receiver by Irradio, with cigarette packet for scale.

tors were found in various forms as a separate unit, built into a "television table," or even disguised as a trough of flowers or a large book (Corghi).

Naturally, some new ideas on styling would be expected in a country such as Italy, and certainly an effort has been made to get away from the ubiquitous "box" round the c.r.t. Some models house the c.r.t. in a plastics moulding which is mounted on top of a flat case or a pedestal containing the chassis, and another approach is to allow the cabinet to reflect to a greater extent than is normal in Great Britain the shape of the c.r.t., whilst keeping the receiver as one unit. C.r.t. sizes seem fairly evenly distributed between "large" (21 and 23-in) and "medium" (17 and 19-in). The smallest set in the show, and probably the cheapest, was an Irradio portable receiver using a 7-in c.r.t. and priced at about £52 sterling, but even this had a full complement of 21 valves.

Some projection receivers were seen, one (Prestal) looking something like a radiogram. The screen is on the inside of the top lid, whilst an L-shaped section carrying a mirror folds down from the front of the set so that the light from the projection unit, which faces the viewer, is reflected back to the screen, the path being several feet long. Other projection receivers treat the unit very much as a piece of apparatus like a cine-projector, rather than as an item of furniture: they thus roughly resemble a streamlined oscilloscope on a tripod or pedestal support.

Few transistor receivers were on show, and we found transistor v.h.f. sets a distinct rarity. The Geloso portable m.w. and f.m. "Sideral" employs nine transistors and four diodes. It has a "V" aerial and the power supply is four 1·5V cells. Sockets provide for output to an earpiece and tape recorder. Valve receivers with v.h.f./f.m. facilities often have tuning ranges covering the television sound channels (also f.m.). Usually the buyer has the choice of two models—one covering Band I, and the other Band III.

A record player—the Framez "Modern Juke-Box" which was seen on several factors' stands—has the interesting construction of a drum-shaped bass reflex chamber with the turntable and amplifier mounted on top. A transparent cover excludes dust when not in use. Small table radiogramophones are popular and the radio section invariably has a comprehensive specification, often having f.m., bandspread s.w. and m.w. facilities.

Test gear exhibits in the components section covered the whole range of equipment for developing and testing receivers, and two firms—L.A.E.L. and T.E.S.—were showing monoscope test-card generators. An impression gained here was that there is great interest in communal aerial systems for TV: this is natural enough as most of the new domestic building in towns is large blocks of flats. Valves and c.r.t.s were included in the displays, both 19-in and 23-in rectangular-cornered c.r.t.s. with "ears" for ease of mounting in the cabinet were on show.

Finally, the Associazione Radiotecnica Italiana (the contemporary of the R.S.G.B.) had a stand with an operating 50-W station (call sign i1ARI) and a display of equipment both "ancient" (1926 onwards) and modern.

50-W amateur radio station i1ARI was manned throughout the exhibition.

Communication via Satellites

NEW STATION FOR EXPERIMENTS WITH REFLECTED SIGNALS

By *MICHAEL LORANT*

AN experimental radio station has been built in the U.S.A. by Bell Telephone Laboratories at Crawford Hill, Holmdel, New Jersey, for tests on the long-distance transmission of radio signals by reflection from artificial satellites of the earth. This may point the way to a whole network of radio terminals for sending telephone messages and television programmes to distant parts of the world. The stations would "bounce" radio signals off dozens of artificial satellites acting as "sky mirrors," and would include facilities for communication experiments with objects in outer space. One of the uses of the Holmdel installation will be to take part in communication projects sponsored by the U.S. National Aeronautics and Space Administration.

One of the projects will test the quality of radio signals transmitted between stations on opposite sides of the United States by means of satellite reflections. Although single telephone channels will be used in the experiment, the objective is to determine whether wide-band television signals could also be transmitted. The microwave radio signals to be used in the experiment will be analysed to obtain information about transmission effects. The data will also be studied to discover the reflection characteristics of satellites in orbit.

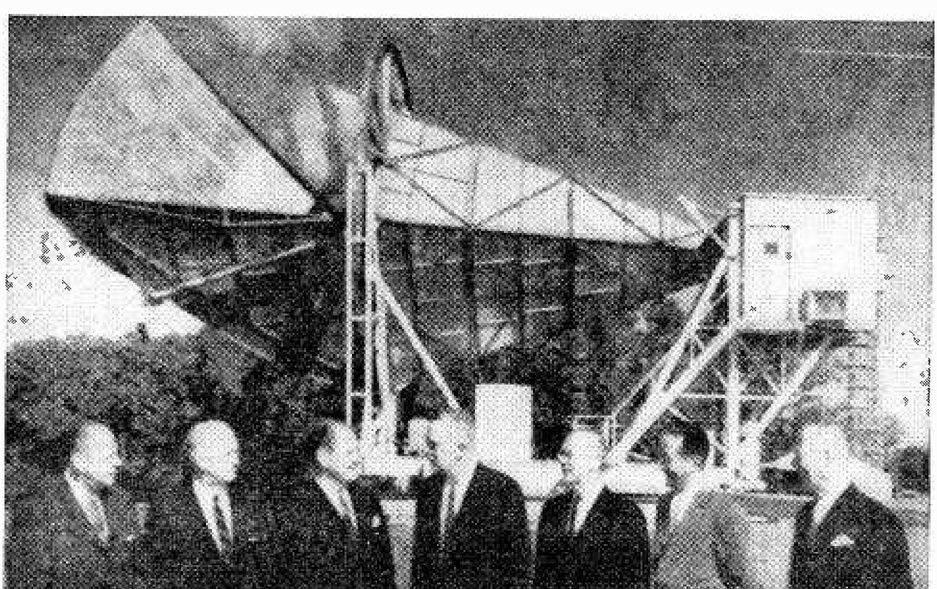
The signals will be received and transmitted between a tracking station of the U.S. National Aeronautics and Space Administration, at Goldstone, California, and Bell Laboratories, which are some 2,300 miles apart.

The Holmdel installation includes a commercially available dish aerial to transmit signals, and a highly directional horn-type aerial for the receiver. The last-mentioned has been designed by Bell Laboratories and is a large version, adapted for tracking, of a horn-reflector aerial which was developed some years ago at Holmdel for radio relay use in the Bell System. It is about 50ft long and the aperture measures about 20ft by 20ft. In conjunction with the horn, a highly sensitive receiver is required. This utilizes extremely low-noise amplifiers, either a pair of parametric amplifiers or masers, or a combination of one of each.

One of the initial and crucial problems in these experiments will be the precise tracking of satellites, and for this purpose Bell Laboratories will devise its own special equipment. Data predicting the "passes" of satellites will arrive in coded form and the new equipment will rapidly convert the information into a form suitable for controlling the aerials.

The first proposal for a system of satellite communications was made in *Wireless World* in 1945 by A. C. Clarke.* In 1955 Dr. John R. Pierce, Director of Communications Research at Bell Laboratories, proposed a system of passive satellite relays. Since then Bell Laboratories have been developing many of the devices required for the tests. A discussion on the general problems of communication by satellites, by R. J. Hitchcock, appeared in the April, 1960, issue of *Wireless World*

* "Extra-Terrestrial Relays," by Arthur C. Clarke, *Wireless World*, October 1945.



Members of the Federal Communications Commision with T. Keith Glennan, administrator of the National Aeronautics and Space Administration, on a visit to the Holmdel station. This untouched picture of the Bell Telephone Laboratories receiver horn was transmitted by reflection from the Echo satellite.

k —and why it is $1{\cdot}38 \times 10^{-23}$

By "CATHODE RAY"

FROM the number and variety of places where *k* crops up, one would guess that it is something important and fundamental. I mean, not counting the times when textbook writers and the like choose *k* to represent *any* constant. The *k* we are after just now is the particular constant associated with the name of Boltzmann.

So far as electronics is concerned, I suppose most people come across it first in connection with noise—the variety called Johnson noise, which is due to the random movements of electrons in resistive parts of circuits. The formula is so simple that it is handed out at quite an elementary stage of the subject: maximum noise power received from any resistance at absolute temperature T, within the frequency band B c/s, is kTB. But even advanced books

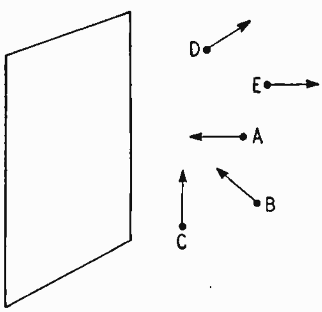


Fig. 1. Of the five molecules shown, only A will hit the surface at right angles. B will hit it at 45°, and the others not at all until they have rebounded elsewhere.

confine their information on *k* to the statement that it is Boltzmann's constant, equal to 1.38×10^{-23} joules per degree.

The next appearance is likely to be quite a bit farther on, when we are learning why semiconductors conduct so much more at a slightly higher temperature, in contrast to metals, which conduct slightly less. Any formulae at all in connection with this inevitably include a term such as $\exp\left(\frac{E-E_F}{kT}\right)$.

Either before or after this we shall have been informed about emission from valve cathodes, in which case the remarkably similar expression $\exp\frac{\phi}{kT}$ may have been brought to our notice.

The more we study these subjects, the more we see of *k*. But we are unlikely to be told any more about what *k* is and why. Well, I suppose it is human nature for curiosity to be aroused in proportion to reluctance to impart information, and I wanted to know.

Looking at what we already have, we note that *k* and T seem inseparable, and since the more talkative of the authorities go so far as to tell us that *k* is reckoned in joules per degree of temperature we deduce without much of a struggle that kT denotes a very small amount of energy. Putting the various contexts together, we might guess that it is the energy of an electron at temperature T. But the energy of an electron can be vastly increased by accelerating it with a high voltage without raising its temperature—or does it? How does one know the temperature of an electron other than by its velocity? And, if so, is temperature relative, in the Einstein sense?

In my schooldays (just after Tom Brown's) we were taught the laws of Boyle and Charles, which together led to the conclusion that the product of pressure and volume of a given mass of gas was directly proportional to its absolute temperature:

$$PV \propto T$$

This, it was admitted, was strictly true only of a fictitious " perfect " or " ideal " gas, but was shown to apply to ordinary air within the rather considerable latitude of school experimental error. (No; you haven't turned over two pages by mistake—this is still " *k*," by "Cathode Ray". Have patience.) The thing can of course be converted into an equation by prefixing T with the appropriate constant, the magnitude of which obviously depends on the mass of gas that is given. It is usual to choose a number of grams equal to the molecular weight of the gas in question, this quantity being called the gram-molecular weight or mole. The point of this choice is that if you weigh the same volume of different gases at the same pressure you find that the weights are proportional to the molecular weights; therefore the number of molecules therein is the same for every gas (Avogadro's law). In one mole there are (so I am told) 6.03×10^{23}. This number is often denoted by N. And the constant (PV/T) appropriate to a mole of gas is denoted by the letter R, making the equation $PV = RT$. In m.k.s. units (except for the grams making a mole) R is 8.32.

We are now approaching the punch line. Remember, the constant connecting $P \times V$ with T for 6.03×10^{23} molecules is R. *The corresponding constant for one molecule is k.* So $k = R/N$.

You don't quite see the connection between this and noise, semiconductors, or thermionic emission? No, I hoped you wouldn't because if you did you ought to be writing this rather than reading it. So let's press on.

For a start, this definition makes *k* look absurd. Gas molecules can only have pressure and volume (and temperature?) when there are lots of them. In this scientific era every schoolboy presumably knows that the pressure of a gas is due to the impact of its countless molecules against the walls of the container, and that most of its volume is really empty space. In fact, the simple gas law we are considering only applies when the molecules themselves fill a negligible part of the volume. If they are crammed close together by very high pressure, $PV = RT$ is not even approximately true. So in relation to the thing for which it is defined k doesn't seem to make sense, and to the things where it might make sense it doesn't seem to have any relationship. What have noise, etc., to do with ideal gases? To find the missing link we shall have to inquire deeper.

First the apparently irrelevant ideal gas. Anyone who is unfamiliar with the details can look them up in a physics book under the heading "Kinetic Theory of Gases." It is usually given some prominence, partly because of its fundamental importance—being connected with so much else, such as the things we are aiming at—and partly because it makes an excellent exercise in the application of still more basic principles, such as Newton's second law of motion.

According to that, force is equal to mass times acceleration. Or, now that mass is no longer assumed to be unalterably constant, the law is often put in the more general form "force equals rate of change of momentum," momentum being mass

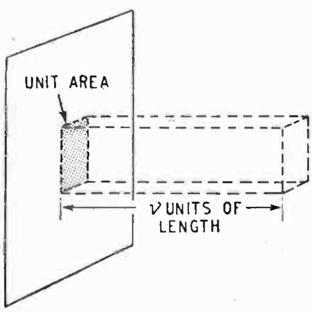


Fig. 2. If all the molecules were moving straight towards the surface with velocity v, all those within the dotted zone (volume, v units) would hit the unit area in one second.

times velocity. When, as is reasonable for most purposes, the mass is regarded as constant, the two statements come to the same thing.

Pressure is force per unit area, and in this case is due to the impacts of gas molecules. It is assumed that they rebound with the same velocity with which they strike the surface, so their change of momentum is twice the momentum with which they approach the surface. If we had to consider individual molecules we would stick at that point, because we wouldn't know the *rate* of change. But fortunately there are such vast numbers of them that their separate impacts merge into an almost steady pressure. All we need know is the number of hits on unit area per second, and of course their velocities. The mass of a molecule of the kind of gas concerned can be looked up in a table.

The difficulty, of course, is that even if we could assume that all the molecules had the same velocity in the direction of their flight (and as it happens we can't) the components of their velocities *towards any surface* would vary from a maximum (say v) for those approaching directly at right angles, down to zero for those travelling parallel to it. And at any given moment a lot of them are moving away. For instance, molecule A in Fig. 1 will hit the surface full in the face, and its original velocity will thereby be altered from v to $-v$, so the change of velocity will be $2v$. Molecule B will strike at an angle of 45°, so its velocity towards the target will be $0.707v$ and the change correspondingly less. Molecules C, D and E will not hit at all on that transit, but only after impacts with other surfaces or molecules.

We can easily find by experiment that gas pressure in a closed space with no draughts is the same in all directions, and conclude that at every moment equal numbers of molecules are moving in all directions. When the effect of this has been calculated, it is found that the result is equivalent to one-sixth as many molecules all moving directly towards the surface. The number hitting unit area in one second in this way is equal to the number contained in v units of volume, as shown in Fig. 2. If N is the total actual number in the whole space, and V its volume, the number of impacts per second is therefore $\frac{1}{6}v$ N/V. The change of momentum is this number multiplied by the mass of each molecule and twice its velocity. So the pressure is

$$P = \tfrac{1}{6}v\frac{N}{V}m2v$$

$$\text{or} \quad PV = \tfrac{1}{3}Nmv^2$$

Although, as I have just said, the velocities of the molecules are not all the same, we know by experience that the pressure is practically constant—so long, at least, as the area on which it is exerted is not very small. So evidently the average of v^2 (which will probably sound more familiar as the mean-square value) is similarly constant. The usual way of indicating that the average is meant is to write it $\bar{v}^2$.

The equation can be rearranged slightly:

$$PV = \tfrac{2}{3}N\left(\tfrac{1}{2}m\bar{v}^2\right)$$

The point of doing this is to make a separate factor of $\frac{1}{2}mv^2$, which should be recognizable as a kinetic energy, in this case obviously of any molecule.

Earlier on we chose a mole of gas as a convenient quantity, and now we shall regard V and N as applying to the same quantity. And as we already know that for this quantity PV = RT we can conclude that

$$\tfrac{2}{3}N\left(\tfrac{1}{2}m\bar{v}^2\right) = RT$$

$$\text{or} \quad \tfrac{2}{3}\left(\tfrac{1}{2}mv^2\right) = \frac{R}{N}T$$

And as k is defined as R/N we arrive at

$$\tfrac{2}{3}\left(\tfrac{1}{2}mv^2\right) = kT$$

So here is our k in association with T, and we have found that this ubiquitous combination is two-thirds of the mean kinetic energy of a molecule of an ideal gas.

The $\frac{2}{3}$ comes into the picture because a molecule of gas has three "degrees of freedom," but that is hardly significant enough for our purpose to take up our time just now.

A much more important point is that the mean k.e. of each molecule—and therefore of the gas as a whole—depends on only one thing: temperature, being directly proportional to it. So the heat of a gas is simply the kinetic energy of its particles.* That is why this subject may be alternatively called the Kinetic Theory of Heat.

We see, then, that k is the constant connecting the kinetic energy of gas molecules with their temperature. So although pressure and volume are meaningless when referred to a single molecule, the fraction of R applicable to a single molecule connects temperature with its kinetic energy, which

* Some authorities have taken to drawing a distinction between random molecular energy derived from a hotter body (which they call heat) and that from mechanical work (which they don't), but this is rather too subtle for our present purpose.

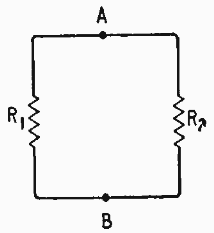


Fig. 3. When two resistors are connected as shown, each feeds the other with Johnson noise power.

en masse, is the cause of the pressure and occupies the volume. And although I can't think of any way of measuring the temperature of a single molecule, it is a tempting idea to calculate it as $\frac{1}{3}m\bar{v}^2/k$. However, because its velocity is varying all the time, authority has declared the concept to be meaningless.

In working out the kinetic theory we made several assumptions, not all of which have been explicitly mentioned. We did say that the presence of molecules mustn't reduce the amount of free space appreciably; in other words, the gas mustn't be too highly compressed. Another thing: there must be no appreciable attraction between the molecules. This assumption also would be unjustified if the gas were very compressed. And it is assumed that the effects of gravity are negligible. This would of course not be true of the air in a mine shaft, where gravity causes the pressure to be very appreciably greater at the bottom than at the top; but it is near enough in a room.

Subject to these, however, we put no restrictions on the size or mass of the molecules. We didn't even say they had to be molecules. In fact, the equation arrived at applies just as much to grains of dust floating about in the gas. They are of course enormously heavier than the molecules, so their mean random velocities for the same kinetic energy per particle are much less. The interesting thing about this is that they and their random (Brownian) movements can be seen and measured through a microscope, and so the theory can be checked by experiment, as was done in the classic experiments by Perrin†. The said random movements of the grains are caused by the molecules bashing into them. Because the grains are so small there are appreciable fluctuating inequalities in the numbers hitting them on each side. These can be regarded as minute differences in pressure, and it is an interesting fact that if the human sense of hearing were a little more sensitive than it is these variations would be audible§. So here is a connection between k and literal noise.

The kinetic theory being true for larger particles than molecules, it is reasonable to expect it to be true for smaller ones, such as electrons. But it might seem to be pushing our luck too far to apply it to the electrons roaming around inside solids. For one thing, we would expect solid material to be too cluttered up to be regarded as an ideal gas! And the rule about forces between the particles being negligible certainly seems to be right out, for mutual electrical repulsion between electrons is relatively enormous.

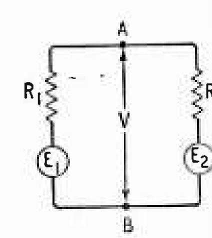
Yet physicists did dare to try assuming that the free electrons in solids behaved like an ideal gas, and the results were so helpful that with considerable modifications this supposition is still the basis for modern theories about the solid state. The reason why the negative electrical charges of the electrons don't completely upset the thing is that they are exactly neutralized by the positive charges of the remaining parts of the atoms, distributed evenly amongst them. And although solids *look* solid, electrons are so exceedingly small that they find plenty of empty space to circulate in. Since Johnson noise is the result of precisely these random movements of electrons in solids, the presence of kT in the basic formula now ceases to surprise.

What does surprise one about the formula for noise power—kTB—is that it says nothing about the number of electrons. At first thought one would have expected—I would, anyway—that the noise created by electrons would depend on how many of them there were. The noise created by a disorderly mob increases with the number of people in it. But then that is noise in the everyday sense; not Johnson " noise," which is a fluctuating electric current. Certainly a very bulky resistor has more random electron movement going on inside it than a small one, but the only thing that matters from a practical point of view is the effect at the terminals. If this were in any sort of proportion to the number of electrons, then if the whole earth as one resistor were connected to a subminiature resistor we would expect the latter to be just about burned out by the noise power it received, which would so much exceed what it could feed into the earth! But we find by experiment that resistors of the same value produce the same noise at their terminals, regardless of their size.

If it were not so, it would not only be contrary to the calculation that kTB is the maximum noise power, but contrary to the general principle known as the second law of thermodynamics, which says that when two bodies are placed in contact there cannot be a flow of random energy from one to the other unless the receiver of energy is at a lower temperature than the giver.

You may have noticed that I referred to " resistors of the same value " and wondered what that had to do with it, since kTB says nothing about resistance. That is because it is the maximum available noise *power*, and in accordance with the well-known matching law the maximum power is received from a generator when the resistance of the load is equal to that of the generator. If two resistors are connected together as in Fig. 3, R_1 generates noise energy which it feeds to R_2. At the same time R_2 is a noise generator feeding R_1. Assuming they are both at the same temperature, the two powers must be equal, so there is no net transfer from one to the other. But the maximum (kTB) flows each way only when $R_1 = R_2$.

Fig. 4. The noise voltage V between the terminals of the resistors is assumed to be the combined result of two noise e.m.fs, E_1 and E_2, in the resistors. If calculations are correct, V must clearly be equal to the open-circuit noise voltage of a single resistor equivalent to R_1 and R_2 in parallel.



What one is usually interested in is the noise

† "Atoms" by Jean Perrin (Constable).
§ According to Stevens and Davis (" Hearing," p. 57) the threshold of normal hearing is about 10dB above this natural noise, but exceptionally acute hearing goes down almost to the same level as the noise.

voltage between the terminals A and B. It can be assumed to be due to noise e.m.fs E_1 and E_2 in series with R_1 and R_2, as in Fig. 4. Then the voltage between A and B due to E_1 (call it V_1) is $\frac{E_1 R_2}{R_1 + R_2}$, and the power fed into R_2 thereby is that voltage squared, divided by R_2. It is a maximum (kTB) when $R_2 = R_1$

$$\left(\frac{E_1 R_1}{2R_1}\right)^2 / R_1 = \frac{E_1^2}{4R_1} = k\text{TB}$$

$$\therefore E_1 = \sqrt{4R_1 \, k \, \text{TB}}$$

Similarly $E_2 = \sqrt{4R_2 \, k \, \text{TB}}$

Now the total noise voltage (V) between A and B, due to *any* resistances R_1 and R_2, is not simply $V_1 + V_2$, because V_1 and V_2 are not in phase; they are random. But the powers due to them are equal, so

$$V^2 = V_1^2 + V_2^2$$

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

$$= \frac{4 \, k \, \text{TB} \, (R_1 R_2^2 + R_2 R_1^2)}{(R_1 + R_2)^2}$$

$$= \frac{4 \, k \, \text{TB} \, R_1 R_2}{R_1 + R_2}$$

Since $R_1 R_2/(R_1 + R_2)$ is the resistance of R_1 and R_2 in parallel, which we can call R, we have found that

$$V = \sqrt{4 \, k \, \text{TBR}}$$

This is as it should be, for $\sqrt{4 \, k \, \text{TBR}}$ is the noise e.m.f. of a resistance R, and therefore its open-circuit voltage.

One factor in this formula (and in the one for noise power too) may arouse some questioning—B, the frequency band. If one had a pure resistance, without any filter or tuning circuit to limit the bandwidth of the noise voltage at its terminals, the formula might seem to be saying that the noise power and voltage would be infinitely large. Which would be absurd in any case, but especially so of a power that we know never exceeds a very small fraction of a microwatt. The explanation is that even an isolated resistor has some self capacitance, and even if there were nothing more it would be enough to limit noise power to a very small amount, as can be found by trying some actual values.

One can, in fact, arrive at a still simpler formula by considering a resistor and a capacitor in parallel. If (as we assume for simplicity) the capacitor itself has no resistance, so that electrically it is a pure reactance, it cannot be the source of any noise, and one can calculate the noise voltage across the common terminals of the resistor and capacitor over an unlimited frequency band. I did this in the June 1956 issue, p. 270, and it came down to the delightfully simple result

$$V^2 = \frac{k\text{T}}{\text{C}}$$

Even the resistance goes out! This may surprise us; but Prof. E. B. Moullin in his book " Spontaneous Fluctuations of Voltage " pointed out that the capacitor *stores* the fluctuating noise energy generated by the resistor. The well-known formula for the energy stored by a capacitor is $CV^2/2$. The energy kT/2 per degree of freedom which we found is possessed by particles *of any size* in a gas has been discovered to be a general principle of very wide application. Applying it to our capacitor, which has one degree of freedom as regards voltage, by equating its energy to kT/2, we get

$$\frac{CV^2}{2} = \frac{k\text{T}}{2}$$

$$\text{or} \quad V^2 = \frac{k\text{T}}{\text{C}}$$

as before. Moullin used this line of thought to find the value of k by experiment.

k in Valves and Transistors

That is all very elementary algebra, but I'm afraid that derivation of the formulae for emission from cathodes and the currents in semiconductors is so far beyond what would be tolerated here that even fairly advanced books on electronics dodge it by referring readers to still more recondite works. The kernel of all such formulae is exp (x/kT), which means e to the power x/kT (for convenience in printing) or, if you insist,

$$e^{\frac{x}{k\text{T}}}$$

where x is a quantity of energy appropriate to the particular problem. In emission, for example, it is the quantity usually denoted by ϕ and called the work function, being the amount of work that an electron has to do to escape from the metal concerned. So it needs that amount of energy or more. The index of e, then, is the ratio between a certain fixed energy and the average energy of electrons at temperature T. ϕ is usually reckoned in electron-volts, so k must be in the same units. Our previous value, 1.38×10^{-23}, is in joules/deg., and a joule is a coulomb-volt, and one electron has a charge of 1.6×10^{-19} coulomb, so k in electron-volts/deg. is $1.38 \times 10^{-23}/1.6 \times 10^{-19} = 8.6 \times 10^{-5}$. ϕ ranges from about 1.8 to 5.5 according to the metal, so for any reasonable temperature ϕ/kT is a fairly large quantity, and exp (ϕ/kT) much larger. The emitted current is inversely proportional to it. But the important point is that a comparatively small change in the index of an exponential function (yes; that is what it is) makes a lot of difference.

Suppose the metal is tungsten, for which ϕ is 4.5, heated to 3,000°K. Then ϕ/kT is 17.4, and e to that power is 75 million. Now suppose the temperature of the emitter fails by 10%, to 2,700°K. The exponential consequently rises to 613 million—a 716% change.

The same sort of relationship applies to the " intrinsic " current in semiconductors, such as the uncontrolled current in transistors, usually designated I_{C0}. That is why I_{C0} rises so steeply with temperature, and special precautions have to be taken in power stages to prevent thermal runaway. Instead of ϕ there is the " energy gap," which is about 0.7eV for germanium and 1.2eV for silicon. That may seem a small difference, but in an exponential function it has a very considerable effect. And so I_{C0} is very much less in silicon transistors than in germanium.

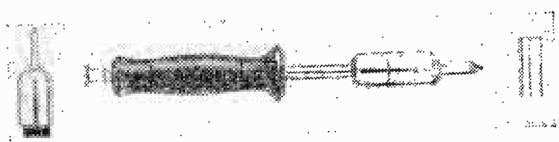
Manufacturers' Products

NEW ELECTRONIC EQUIPMENT AND ACCESSORIES

Chemically-heated Soldering Iron

SOLDERING out-of-doors, even when an electricity supply is available, is not the easiest of tasks. Recourse usually has to be made to a blowlamp, which could be an unwelcome addition to the general paraphernalia of, for instance, the radio amateur on a field day.

The Jenolite "Quik-shot" soldering iron should prove useful in such circumstances because not only is its bit



Quik-shot iron with ⅝-in bit fitted. Also shown are 10,000-calorie heating cartridge and ⅜-in bit.

temperature about 460°C, but also it is heated by an exothermic chemical reaction, the materials for which are contained within a cartridge.

In use the bit is unscrewed and a cartridge inserted. After replacing the bit the reaction is started by releasing a firing plunger mechanism contained in the handle, when the cartridge heats the bit to working temperature in a few seconds. Then the iron remains at soldering temperature for several minutes.

Five bits, ranging upwards in size from ⅜in diameter, are available for the "Quik-shot" and the cartridges are stated to be non-explosive and non-inflammable. Manufacturers: Engineering Supplies Division, Jenolite, Ltd., 13-17, Rathbone Street, London, W.1.

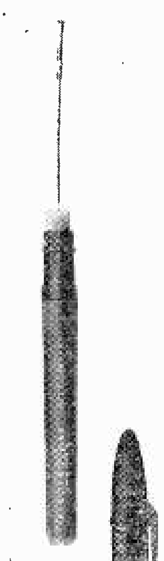
Switch Lubricant Pocket Dispenser

A CONVENIENT pocket-sized dispenser for applying Electrolube switch cleaner and lubricant economically to normally inaccessible parts has been introduced by Electrolube Ltd., Oxford Avenue, Trading Estate, Slough, Bucks.

A sharp pull on the fountain-pen type cap releases a thin 3-in long flexible tube and controlled drops of lubricant can then be applied exactly where required by squeezing the flexible body of the pen reservoir.

Electrolube is claimed to loosen tarnish and corrosion providing clean contacting surfaces and thus effectively reducing contact resistance in all types of switches, sockets and valve holders to mention a few items only.

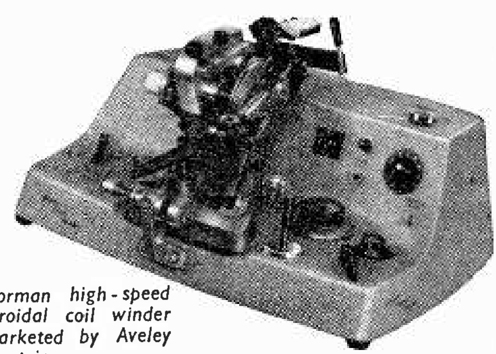
Two forms of the lubricant are available in the pen-type dispenser; No. 1 is for most electronic applications where there is no arcing at the contact surfaces and its container has a green-coloured cap. No. 2 is for use on electrical contacts where arcing is liable to occur in normal operation and its container has a red-coloured cap. Electrolube is available only to electrical and electronics industry personnel and distribution is through recognised trade channels. No. 1 pen dispenser costs 10s and No. 2 dispenser 12s.



Electrolube pen dispenser with cap removed showing the extended nylon tube.

Toroidal Coil Winder

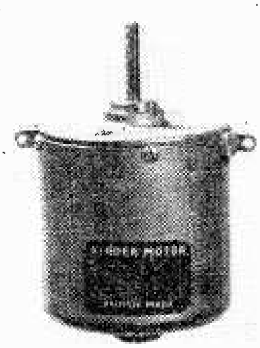
SHOWN in the illustration is the Gorman Model 600 high-speed toroidal coil-winding machine recently made available in the U.K. by Aveley Electric. It winds at any pre-set speed up to 1,200 turns per minute with wires of between No.27 s.w.g. and No.48 s.w.g. inclusive, and accommodates cores up to 2in outside diameter.



Gorman high-speed toroidal coil winder marketed by Aveley Electric.

Winding can be carried out over the full 360° of the toroid or over any lesser angle as required. An electronic transistorized turns counter is embodied but provision is made for attachment of an alternative type of counter which stops the machine after any pre-determined number of turns has been completed.

Further details are obtainable from Aveley Electric Ltd., Aveley Industrial Estate, South Ockendon, Essex.



Six-pole "Kinder" motor for battery-operated tape recorders and record changers.

Small D.C. Motor

DESIGNED to meet the requirements of manufacturers of battery-operated record players, record changers and tape recorders, the "Kinder" range of 3-pole and 6-pole motors is being marketed by Greencoat Electronics, Ltd., 2, Princes Row, London, S.W.1.

For single-speed record players there are a number of types including the 6C, designed for 4.5V battery operation with a torque of 1gm-cm at 45mA and speed of 1,810 r.p.m. Successful operation of some existing

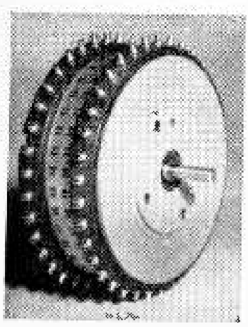
4-speed record-changer mechanisms has been achieved with the types 3C and 4C operating from 6-V and 9-V batteries respectively, the latter giving a torque of 1.5gm-cm for a consumption of 23mA.

Where a higher torque is required, as in tape recorders, the 6-pole motor will, for example, give a torque of 6gm-cm for 63mA at 6V.

All these motors are speed-controlled by a centrifugal switch arranged to open-circuit part of the motor windings when the critical speed is exceeded.

Adjustable "Law" Potentiometer

SHOWN in the illustration is a new type of precision potentiometer embodying a toroidal, wire-wound, linear resistance with 33 intermediate tappings at 10° intervals, in addition to the usual end and slider connections. The intermediate tappings are brought out to a double ring of turret-type soldering tags arranged round the circumference of the component. The purpose of the intermediate tappings is to enable fixed resistors to be connected externally across various sections of the toroidal winding so that any non-standard "resistance law" may be obtained and readily modified should the occasion demand.



Miles Electronics adjustable "law" precision potentiometer.

The model shown is the Type MCD30/FG and this is housed in a machined aluminium case measuring 3in in diameter and 1¼in deep (back to front). The wiper spindle rotates through 340° and is 0.1875in in diameter. Provision is made for ganging up to six potentiometers in tandem. This model is available in linear resistance values of from one to 100kΩ and with tolerances of ±0.5%, ±0.25% or ±0.2% as required, with a nominal rating of 6W.

There is also a Type MCD30/CT which has a centre-tapped toroidal linear resistance winding, also provided with intermediate tappings. Further details can be obtained from Miles Electronics, Ltd., Shoreham Airport, Sussex.

Coaxial Change-over Relay

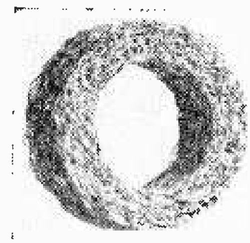
B. & R. RELAYS LTD Type A07 coaxial relay can be used at frequencies up to 500Mc/s (s.w.r. at 300Mc/s, 1.15 maximum). The actuator consists of a solenoid, whose central armature is extended to carry the moving contact assembly in the contact chamber. Projecting into the contact chamber are fixed contacts joined to the inners of the flying coaxial leads. In the unenergized condition two leads are joined and the third is earthed; when the solenoid is energized (power required 2W) the armature moves into the coil, changing the connections so that the input is joined to the other flying lead. Again the unused contact is earthed. The characteristic impedance of the cables, which may be 50 or 75Ω, is preserved by connecting a capacitor in impedance equal to the cables entering the relay from the fixed contacts to earth. This capacitor is formed by the contact assembly itself, and ensures perfect matching for the r.f. signal (Patent No.812546). Power handling capacity is 100W: the relay resists accelerations in any plane up to 10g and at right angles to the longitudinal axis up to 20g, between 50 and 500c/s.

Type A07 coaxial relay is about 2-in high.

The address of B. & R. Relays, Ltd. is Temple Fields, Harlow, Essex.

Wire Mesh R.F. Shields

THEORETICALLY the ideal screening for r.f. apparatus is a metal container without openings and with all joints and seams welded. Although shielding of this kind is not practicable a close approach to it seems to be attainable by the use of a screening material described as "Knit Mesh." This is a knitted, not woven, wire mesh and as available for electronic applications takes the form of annular spindle gaskets, rectangular gaskets for panels, lids and hinged flaps on screening cabinets and also for certain fittings of screened rooms. Another form is a combined r.f. shield and air seal for sealing the doors or "drawers" of cabinets housing electronic apparatus. This consists of a "Knit Mesh" covering over a rubber tube.

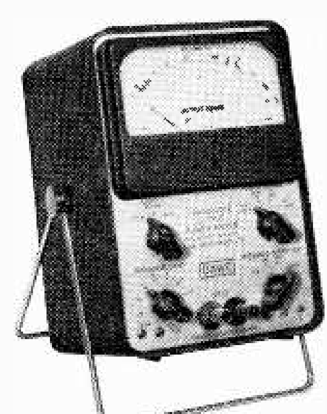


Knit Mesh r.f. seal for spindles of controls on electronic equipment.

These strips and gaskets can be made in any metal capable of being produced in filament form and in a wide range of sizes and patterns with metal content ranging from 50% to 99% as required. Further details can be obtained from Knit Mesh Ltd., 36, Victoria Street, London, S.W.1.

Transistorized Output Power Meter

IN the Dawe Type 610C a.c. output powers are measured simply by amplifying the voltage across a suitable resistor load. Forty alternative load values are provided, distributed at approximately equal logarithmic intervals from 2.5Ω to 20kΩ. By determining the load in which maximum power is developed, source impedances can also be measured. The resistive loads are accurate to ±2% from 20kΩ down to 20Ω, this accuracy decreasing to ±(5% +0.25Ω) below 20Ω. Four alternative power ranges are provided with full scale deflections of 10, 100, 1,000 and 10,000 mW. Power measurements are accurate to within ±1dB at frequencies between 20c/s and 20kc/s. This accuracy is not affected if direct current is superimposed on the a.c. current through the load, unlike the case with power meters having the more usual multi-ratio transformer design. The 610C is battery-operated. It costs £68 (provisional) and is manufactured by Dawe Instruments Ltd., of Harlequin Avenue, Great West Road, Brentford, Middlesex.



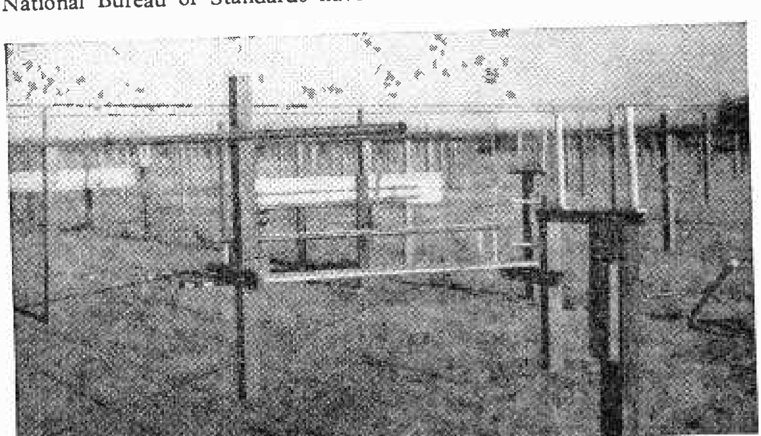
Dawe Type 610C transistor output power meter.

Technical Notebook

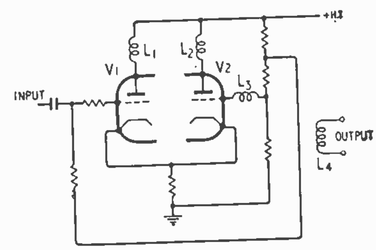
Home-Made High-Vacuum technique described by J. H. Owen Harries in the August 1960 issue of *Electronic Technology* enables pressures as low as about 3×10^{-8}mm of mercury to be obtained without expensive pumping equipment or special cleanliness precautions. In this technique the assembly to be evacuated is first cleaned simply by washing it in a household detergent solution. It is then baked in a home-made oven at about 350°C for about an hour. The pressure is first reduced to about 3×10^{-4}mm of mercury either by means of an ordinary mechanical pump or alternatively by filling the assembly with carbon dioxide which is then absorbed in refrigerated activated charcoal. A further reduction in the pressure down to about 3×10^{-8}mm of mercury is then obtained by means of BaAl and Ti getters. The pumping action of a Penning ion current pressure gauge is then used to keep the pressure at this level even with relatively "dirty" assemblies.

Acoustic D/F for the Blind is possible with the Valradio "Sondar". In this a portable transistorized battery oscillator and directional conical horn loudspeaker produce bursts of 10,000c/s sound waves at a repetition frequency of about 75/sec and a peak power of about 20W. By listening to the reflected signal, a suitably-trained blind person can determine the distance and angular location of objects up to about 20 feet away.

"Scatter" Radiation is more promising than reflected radiation as a source of information about the upper atmosphere. Whereas reflected radiation can only provide information about those layers in which ionized electrons are dense enough to produce reflection, re-radiation or "scatter" can be excited from all levels of the atmosphere above about 50 miles. In particular, scattered radiation can be observed from above the normal reflecting layers: in fact the U.S. National Bureau of Standards have observed scatter from as high as 400 miles and it is hoped to extend this range. In addition, scattered radiation should in principle enable measurements to be made of the temperature as well as the electron density in the upper atmosphere. In the U.S. National Bureau of Standards measurements a frequency of 41Mc/s and peak pulse power of 6MW are used. Vertically-returned scatter is detected using an aerial made up of as many as 1024 half-wave dipoles and covering in all 4 acres: part of this aerial is shown in the photograph.



Confluxer is a circuit developed by Lintronic Ltd. (47 Charing Cross Road, London, W.C.2) for generating pulses of constant charge from zero crossings of any types of waveform, even slowly-varying ones. The quantity of charge generated depends almost solely on a passive element and so does not vary by more than about 1% for extreme changes in valve characteristics or power supply voltages. The Confluxer thus gives a mean output accurately proportional to the input frequency or pulse rate. The circuit of the Confluxer is shown in the diagram. The four windings (L_1, L_2, L_3, L_4) are all wound on the same toroidal core, a core material with a rectangular hysteresis loop and high retentiveness being chosen. In the quiescent state valve V1 is conducting much more heavily than V2 since its grid is connected to a more positive potential. In this state the core is thus saturated in the sense determined by the winding of L_1. When a negative-going signal is fed to the grid of V1 this reduces the current in this valve. This produces a voltage across L_1 which in turn induces voltages across L_2 and L_3. These are wound in such a way that this lowers the anode voltage of V2 and



raises its grid voltage, thus increasing the current in V2. The whole action is regenerative and V2 soon conducts heavily while the current in V1 is materially reduced. This reverses the magnetization of the core to saturation in the opposite sense, since L_1 and L_2 are wound in opposite senses. When the input waveform goes positive V1 again conducts heavily while the current in V2 is materially reduced: this again reverses the magnetization of the core. Pulses are thus induced in the output winding L_4 due to the reversals of the core magnetization. Since the total flux change during each such reversal depends almost solely on the core parameters, output pulses of very nearly constant charge are generated. In fact either a 12AT7 ($\mu=60$) or 12AU7($\mu=16$) can be used as the valve with little change in the output.

Very Long Electromagnetic Waves, of the order of 20,000 metres or so, were at one time used extensively for long-distance radio communications, but once it was realized that world coverage was possible on short waves, with only a fraction of the power needed for long-wave transmission, the long waves experienced a spell in the doldrums. However, in recent years interest in them has revived for certain specialized applications and about three years ago the U.S. National Bureau of Standards sponsored a symposium on the very low frequencies (VLF) in the band 3kc/s to 300kc/s.

In January of this year N.B.S. invited some 50 prominent scientists and radio engineers to a conference at their Bolder (Colorado) laboratories for the express purpose of exchanging information and ideas on the propagation and potential applications in the communications field of electromagnetic waves below 3kc/s.

According to a brief report of the conference in the May, 1960 *N.B.S. Technical News Bulletin* at these extremely low frequencies (ELF waves they are called) terrestrial and extra-terrestrial sources radiate electromagnetic energy in one form or another. It is, of course, well known that ordinary lightning discharges radiate considerable energy on frequencies down to 10c/s or lower and these "signals" have been used for some years to study propagation conditions in this region of the electromagnetic wave spectrum.

Frequencies of this order appear to be propagated with very low attenuation and to penetrate rocks and soil with relatively small loss. They have been used extensively in geophysical survey work.

It is also said in the N.B.S. report that because the ELF waves exhibit certain magneto-ionic characteristics they might well be expected to penetrate the ionosphere and be usable for communication with space vehicles. Such penetration appears to be feasible on theoretical grounds at about 3kc/s, where it is said, there is evidence of a "window" in the ionosphere. Furthermore, these low frequency waves should be diffractable around planetary bodies.

Variable-Tuned Microwave R.F. Stage—even though it is only passive—is an unusual feature of the American Polarad Model R receiver imported into this country by B. & K. Laboratories. The tuning of the r.f. cavities is carried out by plungers which are mechanically ganged to the klystron local-oscillator tuning control. Two coupled cavities are used to give the usual improvements of a flatter band-pass response with steeper sides.

Adhesive-Backed P.T.F.E. Tape is now available from the Fluorocarbons Department of the Radio and Electronic Components division of A.E.I. Samples applied to steel showed a peel strength of the order of 2lb per inch width of tape. Although the adhesive becomes thermoplastic above 300°F it is still useful up to 390°F. It has a high resistance to attack by acids and alkalis but is affected by most organic solvents.

Double Frame-Grid structure with two pairs of parallel backbones round which grids are wound is used in the new 8P1 valve developed by the G.P.O. By making the extra (second) pair of backbones with a slightly greater diameter than the first, the second (screen) grid can be positioned very close to the first. This allows an anode potential as low as about 45V to be used which is a great advantage in the submarine telephone cable repeater application for which this valve has been designed. A high slope of about 25mA/V is obtained by the normal utilization of the frame grid method of construction to wind the control grid very close to the cathode.

Low Melting-Point Glasses suitable for encapsulating electronic components have been recently developed by Drs. S. S. Flaschen and A. D. Pearson of the Bell Telephone Laboratories. The glasses are made up of arsenic and thallium together with various proportions of sulphur or selenium. These new glasses become fluid at temperatures between 125° and 350°C—i.e. some 300° to 400°C lower than does any previously known glass. When fluid the new glasses have viscosities which enable an object to be coated simply by dipping it into the glass. The glasses have resistivities which vary from 10^6 ohm-cm to over 10^{14} ohm-cm, and thermal expansion coefficients of the order of 30×10^{-6} per °C. The solubility characteristics of the new glasses are similar to those of glasses in general except that they are insoluble in hydrofluoric acid.

NOVEMBER MEETINGS

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

LONDON

1st. I.E.E.—"Transistor instrumentation in rockets" by G. G. Haigh at 5.30 at Savoy Place, W.C.2.

2nd. I.E.E.—"The ionosphere—a review of recent progress" by Professor W. J. G. Beynon at 5.30 at Savoy Place, W.C.2.

2nd. Brit.I.R.E.—Discussion on "Radar—pulse or C.W.?" at 6.30 at the London School of Hygiene and Tropical Medicine, Keppel St., W.C.1.

2nd. British Kinematograph Society.—"Transmission of films by cable using the slow scan method" by C. B. B. Wood and J. J. Shelley (B.B.C. Research Department) at 7.30 at the Central Office of Information, Hercules Road, S.E.1.

7th. I.E.E.—Discussion on "The impact of television on society" opened by Lord James of Rusholme at 5.30 at Savoy Place, W.C.2.

9th. Brit.I.R.E.—"Diagnostic applications of ultrasonic" by T. G. Brown at 6.30 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

9th. Institution of Production Engineers.—"Induction heating" by D. G. Jones at 7.15 at 10 Chesterfield Street, W.1.

10th. Television Society.—"Masers and parametric amplifiers: their use in ultra low noise receivers" by C. R. Russell (G.E.C. Research Laboratories) at 7.0 at the Cinematograph Exhibitors' Association, 164, Shaftesbury Avenue, W.C.2.

10th. Radar & Electronics Association.—"V.H.F. aerial techniques" by C. A. Burgess at 7.30 at the Royal Society of Arts, John Adam Street, W.C.2.

11th. I.E.E.—"The future of 'electrics' and 'electronics' in aircraft and guided missiles" by the Rt. Hon. the Viscount Caldecote at 5.30 at Savoy Place, W.C.2. (Joint meeting with the Royal Aeronautical Society.)

14th. I.E.E.—Discussion on "Tunnel-diode applications and circuitry" opened by Dr. G. B. B. Chaplin and Dr. R. W. A. Scarr at 5.30 at Savoy Place, W.C.2.

16th. I.E.E.—"Radiocommunication in the power industry" by E. H. Cox and R. E. Martin at 5.30 at Savoy Place, W.C.2.

16th. Brit.I.R.E.—"Digital computing elements for instructional use" by Lt.-Col. I. W. Peck at 6.30 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

18th. Institution of Navigation.—A one-day symposium held jointly with the British Interplanetary Society on "Navigation for the early exploration of the moon" at 10.0 at the Royal Geographical Society, 1 Kensington Gore, S.W.7.

18th. Institution of Electronics.—"Magslips, synchros and their applications" by J. H. Batchelor at 7.0 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

22nd-24th. I.E.E.—Conference on electronic telephone exchanges at Savoy Place, W.C.2.

23rd. Brit.I.R.E.—"Objective and subjective requirements for loudspeakers" by F. H. Brittain at 6.30 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

25th. Television Society.—"Measurement techniques for television broadcasting" by L. E. Weaver and I. J. Shelley (B.B.C.) at 7.0 at the Cinematograph Exhibitors' Association, 164, Shaftesbury Avenue, W.C.2.

30th. I.E.E.—"The potentialities of artificial earth satellites for radiocommunication" by W. J. Bray at 5.30 at Savoy Place, W.C.2.

30th. British Kinematograph Society.—"16-mm fast pulldown television recorders" by M. E. Pemberton (Marconi Research Laboratories) at 7.30 at the Central Office of Information, Hercules Road, S.E.1.

BIRMINGHAM

23rd. Brit.I.R.E.—Discussion on "The various routes to professional qualifications in electronic engineering" with Professor D. G. Tucker in the chair at 6.15 at the University, Edgbaston.

23rd. Television Society.—"Eurovision" by J. H. Holmes (B.B.C.) at 7.30 at the New Physics Lecture Theatre, The University.

BRISTOL

22nd. Brit.I.R.E.—"Transistors in control circuits" by E. Woltendale at 7.0 at the School of Management Studies, Unity Street.

CAMBRIDGE

15th. I.E.E.—"Channelling — a sketch" by T. B. D. Teroni (Electronics and Communications Section chairman), at 8.0 at the Cavendish Laboratory.

24th. I.E.E.—"Television recording: a survey of the problems and methods currently in use" by J. Redmond at 8.0 at the Cavendish Laboratory.

CARDIFF

23rd. Brit.I.R.E.—"Radio navigational aids in aircraft" at 6.30 at the Welsh College of Advanced Technology.

CHELTENHAM

22nd. Society of Instrument Technology.—"The operation and control of ERNIE" at 7.30 at the Belle Vue Hotel.

CHESTER

14th. I.E.E.—"Teaching and learning machines" by C. E. G. Bailey at 6.30 at the Town Hall.

DERBY

17th. Society of Instrument Technology.—"The wavelength standard of length" by K. J. Hume at 7.15 at the Derby & District College of Technology, Kedleston Road.

DUBLIN

17th. I.E.E.—"Aviation, navigational systems" by G. Jones at 6.0 at the Physical Laboratory, Trinity College.

EDINBURGH

8th. I.E.E.—"Advances in semiconductor devices and circuits" by Dr. J. Evans and T. H. Walker at 7.0 at the Carlton Hotel, North Bridge.

9th. Brit.I.R.E. — "V.H.F./F.M. transistor receivers" by H. A. Heins at 7.0 at the Department of Natural Philosophy, The University, Drummond Street.

FARNBOROUGH

22nd. Brit.I.R.E.—"Radio aids for automatic landing developed by the Blind Landing Experimental Unit" by J. S. Shayler at 7.0 at Farnborough Technical College.

GLASGOW

7th. I.E.E.—"Advances in semiconductor devices and circuits" by Dr. J. Evans and T. H. Walker at 6.0 at the Institution of Engineers and Shipbuilders, 39, Elmbank Crescent.

9th. I.E.E.—"The digital computer" by Dr. I. Cochrane at 6.0 at the Institution of Engineers and Shipbuilders, 39 Elmbank Crescent.

10th. Brit.I.R.E. — "V.H.F./F.M. transistor receivers" by H. A. Heins at 7.0 at the Institution of Engineers and Shipbuilders, 39 Elmbank Crescent.

IPSWICH

28th. I.E.E.—"An introduction to electronic computers" by R. C. M. Barnes at 6.30 at Electric House.

LEEDS

8th. I.E.E.—Discussion on "City and Guilds or National Certificate?" opened by G. P. Evans at 6.30 at the College of Technology, Calverley Street.

LIVERPOOL

16th. Brit.I.R.E.—"The design of high quality sound reproducing equipment" by R. T. Lakin, K. Davin and F. C. Gibson at 7.0 at the Adelphi Hotel.

28th. I.E.E.—"Thermistors—their theory, manufacture and application" by Dr. R. W. A. Scarr and R. A. Setterington at 6.30 at the Royal Institution, Colquitt Street.

MALVERN

3rd. Brit.I.R.E.—"Electronic sector scanning" by Professor D. G. Tucker at 7.0 at the Winter Gardens.

MANCHESTER

3rd. Brit.I.R.E.—"Video-tape recording" by P. Denby at 7.0 at the Reynolds Hall, College of Technology.

9th. I.E.E.—"The applications of microwaves" by Professor A. L. Cullen at 6.15 at the Engineers' Club.

NEWCASTLE-UPON-TYNE

9th. Brit.I.R.E.—"Distribution of sound and television by wire" by A. W. Mews at 6.0 at the Institution of Mining and Mechanical Engineers, Neville Hall, Westgate Road.

14th. I.E.E.—"Thermistors—their theory, manufacture and application" by Dr. R. W. A. Scarr and R. A. Setterington at 6.15 at the Rutherford College of Technology, Northumberland Road.

21st. I.E.E.—"Radiocommunication in the power industry" by E. H. Cox and R. E. Martin at 6.15 at the Neville Hall, Westgate Road.

RUGBY

16th. I.E.E.—Faraday Lecture on "Transistors and all that" by L. J. Davies at 6.30 at the Temple Speech Room.

SOUTHAMPTON

8th. I.E.E.—"Error correction in digital data transmission system" by Dr. J. E. Meggitt at 6.30 at the University.

STOKE

18th. I.E.E.—"Radiocommunication in the power industry" by E. H. Cox and R. E. Martin at 7.0 at the Technical College.

TORQUAY

16th. I.E.E.—"The Post Office Type 10P valves for submarine telephone repeaters" by F. H. Reynolds at 3.0 at the S.W.E.B. Electric Hall.

WOLVERHAMPTON

9th. Brit.I.R.E.—"Modern computer techniques," by K. C. Johnson at 7.15 at the College of Technology.

RANDOM RADIATIONS

By "DIALLIST"

"Needles"

CURIOUS—isn't it?—how often a new wireless project is found to be a cause of unwanted interference.* That may be the last nail in the coffin of operation "Needles" suggested by the U.S. Army Air Force and referred to on page 484 of the October issue. The idea is to put large numbers of metal strips into orbit round the earth and to use them as reflectors to help world-wide communications. When the plan was announced an outcry arose from the International Scientific Radio Union, which was meeting in London. Professor A. C. B. Lovell told the meeting that "needles" would seriously hamper both radio astronomy and visual astronomy. There's also the possibility that it might have serious effects on long-distance radar. You probably remember "Window" used by our bombers in the last war. On their journeys out and home they dropped quantities of metallized strips and these completely confused enemy radar. American scientists say that it should be possible to work out a position for a belt of "needle" dipoles in which they wouldn't be in anyone's way. That may be so; but it has to be borne in mind that once you put things into orbit they're there and you can't get 'em down again until they fall to earth in their own good time.

Do They Still Want Lines?

WOULD a satisfactory system of removing the lininess from television images stand a good chance of acceptance by the man-in-the-TV-street if introduced today? I rather think that it would. Spot-wobble was made part of Ekco receivers at a time when all sets had manual focussing. There's no doubt that users of sets with this kind of focusing rely largely on the lines to indicate whether or not correct adjustments have been made. But in all modern sets the focus is adjusted by the man who installs or services the set and it stays put. One would have thought that in these days of smallish living rooms and larger and larger TV screens a line eliminating system would be welcomed, at any rate by those whose sets have no manual focus controls. Myself, I think that spot-astigmatism (or elongation) is probably better than spot-wobble. This can now be done optically by a method evolved and at present being developed by the Saba company in Germany.† In this a transparent plastic panel in which horizontal lenticlar grooves are cut is placed in front of the viewing screen of the c.r. tube. The line structure is made invisible and a good, clear picture results.

Telegazing

WHY should there be so strong an urge to watch other people at work? I'm thinking of manual work, such as digging or building. The urge is certainly there and some five years ago one big firm of building contractors did their bit towards satisfying it by erecting platforms from which all the world and his wife could see what was going on. These platforms have always been well patronized and now the firm has gone one better. On a site at the junction of Gracechurch Street and Fenchurch Street in London Taylor Woodrow have fitted the platform with Marconi closed-circuit TV. The public has a fine view of what's afoot on a 21-in receiver. Not only that, but a remote control unit near the receiver enables the watcher to move the camera in bearing and in elevation, so that different parts of the site can be viewed. As the job isn't due to be completed until the autumn of next year, telegazers are assured of a long spell of watching.

Radio Doctors

IF sufficient practitioners in a locality are willing to play, a scheme has been worked out which may result in a kind of wireless-linked medical service. The idea is that the cars of all who take part shall be fitted with suitable v.h.f. transmitter-receivers like those used in radio taxi systems. Doctors on their visiting rounds would be in constant touch with a central transmitting station. In the ordinary way most general practitioners have to find a telephone call box or return to their surgeries in the course of their visiting rounds to see whether any messages have come in for them. This wastes time and would become unnecessary if they were in touch with a central station. There is also the important consideration that in case of an accident or other emergency medical help would be available in the shortest

* When the satellite balloon "Echo" was put into orbit Capt. H. J. Round pointed out to us that it would be "aperiodic" and would not be an unmixed blessing since it would increase the field strength of interference.—Ed.

† *Wireless World,* August 1960. p. 372.

possible time. The initial cost of installing transmitter and receivers is substanial but it seems to me that the saving of time makes this well worth while.

Cheaper C.R. Tubes

IT'S good to see that the prices of cathode-ray tubes have been further reduced. That and the twelve months' guarantee *and* the additional fact that the rebuilding or reconditioning of tubes that have become defective is now so widely practised have removed the somewhat hard-up viewers' worst headache. It's no longer a disaster if the c.r.t. packs up, for it can be reconditioned or replaced at no staggering cost. I've known folks who were frightened in the old days of going in for TV by the tales of calamity they heard from others. The c.r.t. might "go"—and too often it did—soon after the expiring of the then six months' guarantee. Since reconditioning hadn't arrived then, there was nothing for it but to spend a heap of money on a new tube and, if you hadn't got it, you had to forgo viewing until you'd saved up.

For Blind Switchboard Operators

THE Royal National Institute for the Blind realizes how much electronics has already done to help blind people and is always on the look out for possible new applications. Recently it suggested to Mullard Research Laboratories that the transistor and the photoelectric cell might be made to give assistance to blind operators of telephone switchboards, and the result has been the development of prototype equipment which is now undergoing field trials. It is designed for use with the Post Office P.A.B.X.1 type of board and the board itself needs no modification. A standard fitting of the board issues an audible warning when some action is needed and a carriage containing a photocell is then moved by the operator along rails which form part of the board. If any call lamp is glowing, the cell responds when over it and causes a transistor oscillator and a loudspeaker to give rise to a note—steady if the lamp glows continuously and interrupted if it is flashing. I've little doubt that first the R.N.I.B. and then blind operators who come to use it will be delighted with the simple device.

UNBIASED

By FREE GRID

"Things Great and Small"

I HAVE followed with interest and growing impatience the correspondence in recent issues regarding the system of numerical prefixes put forward by A. P. G. Peterson and quoted by Frederick T. Van Veen in a letter to the Editor (September issue). But the letter of D. B. Pitt (October issue) has finally exhausted my patience, and I can hold my peace no longer.

Mr. Pitt, by inference, pleads for the retention of certain prefixes. All those he quotes are as numerically meaningless as mega (great). The first three he mentions are respectively derived from the Latin *nanus* (dwarf), and Greek *gigas* (giant) and *teras* (monster). It is a minor point, but I would remind him that these two latter words are far from "dead" as he implies in the earlier part of his letter. They are all very much alive and used in modern Greek. The Latin prefix "pico," which Mr. Pitt also favours, probably comes to us from the *litera picata* of mediæval manuscripts (later it passed into the jargon of printers); it could also come from the non-U Latin source which gives us the Italian *piccolo* (small).

Unlike Mr. Pitt, Mr. Van Veen disapproves of these words as much as I do but he, too, falls into grievous error. After giving us a table of the Peterson system he says: "It is a pity that Peterson's article [in an I.R.E. publication] wasn't published ten years ago before such alogical absurdities as giga won their acceptance through default." It is clear Mr. Van Veen is ignorant of the fact that the alogical absurdities which he deplores were decried, not ten but over twelve years ago, and a new system proposed which, in my opinion, is far better than the one now put forward by Mr. Peterson.

This pre-Peterson 1948 system was a logarithmic one in which all prefixes had a definite numerical value. It is best explained by the accompanying table which I reproduce from page 304 of the August, 1948, issue of *Wireless World* where

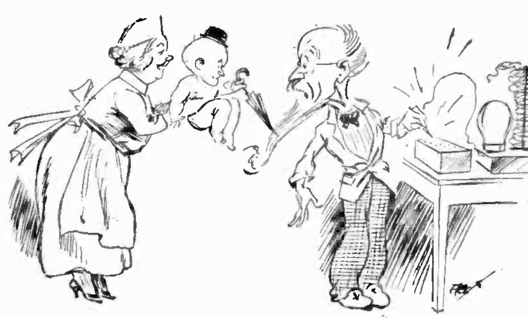
10^3	Treis	10^{-3}	Tres
10^6	Hex	10^{-6}	Sex
10^9	Ennea	10^{-9}	Novem
10^{12}	Dodeka	10^{-12}	Duodecim

it originally appeared. The Greek multiple prefixes in the left-hand column and the Latin sub-multiple ones in the right-hand column can, for the sake of euphony, be slightly modified by omitting the final letter, if a consonant, or by adding a vowel, as is done freely in the ordinary metric system where, in addition, "k" usually becomes "c" as in decametre.

In this 1948 system, a megacycle would be called a hexacycle and a microfarad would become a sexofarad. The system could be extended more or less indefinitely. We should lose our old friend "kilo," of course, but does that matter? It is not, and never was, the word for a "thousand" in Greek or any other language but was introduced arbitrarily into French in 1795 to prevent people talking of chiliometres. In any case, a few years ago we lost the old familiar "capacity" and "condenser" but we soon got used to it.

18-track Tape

RIGHT from the moment of my birth as I arrived just after Big Ben had boomed out the first stroke of midnight ushering in April 6th, so causing my father to lose a year's income-tax allowance for me, I have been unpunctual.



"From the moment of my birth."

It was a bad start and unpunctuality has always seemed to dog me ever since. Incidentally, with unpunctuality goes laziness; indeed, some people say the latter is the cause of the former. I certainly am lazy and one of the results is that I like to loll back in a comfortable armchair while Mrs. Free Grid reads one of my favourite books to me.

But frequently her time and temper are both short, and I am wondering, therefore, if it would not be possible for some publisher to issue for people like me, tape recordings of books read by somebody specially trained for the job. The ideal way would be to have each book dealt with on the lines of Mrs. Dale's diary, and to have the purple passages in love scenes actually acted, vocally speaking, by some ravishing blonde and tender-tongued swain.

All this would, of course, take yards and yards of tape (even if it were of the later 4-track variety) for a complete novel. But recorders have now been designed for the blind in which no fewer than eighteen tracks are squeezed on to a ½-in tape. This gives a maximum playing time of no less than twenty hours which would, I think, be enough even for the garrulous Mrs. Dale. For some time, of course, there have been talking-books for the blind but mainly on discs which are now to be allowed to fade slowly away like old soldiers. Henceforth all recordings are to be on this 18-track tape.

I think the most interesting part of the apparatus is the cassette. This holds not only a full-length novel—or what have you—on an endless tape but has its own built-in playing head. The idea is, of course, to simplify changing the record for blind users.

For those of us with the good fortune to have the use of our eyes, such an arrangement would not be really necessary but it would certainly simplify mass production of these records. The advantage of this would be that it would lessen overhead expenses to have only one type of record and so possibly make them available at a lower price to the Royal National Institute for the Blind which, in co-operation with St. Dunstan's, organizes the Nuffield Talking Book Library for the blind.

B.B.C. Scrapbooks

I WAS very interested to read the letter (October issue) from Vernon Harris, the producer of the B.B.C. Scrapbooks, in which he explains that the B.B.C. never allows genuine morse signals to be broadcast in dramatic productions.

I was interested to learn, too, that the errors of the times are also placed on record by putting them into the mouths of people like the young woman at the New Year's Eve ball. It is certainly a good idea, and if I am ever in doubt about my facts when writing for *Wireless World* I must remember to put them into the mouth of Mrs. Free Grid.