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The New Bearley Receiving Station

E. G. BRONSDON†

U.D.C. 621.396.62.029.5(424.8)

Sir John Wall, Deputy Chairman, Post Office Board, formally opened the new Bearley receiving station on 23 November 1967. The radio receivers have been designed or adapted for remote automatic tuning so that initially they may be controlled from a central control position. Ultimately they may be controlled from a remote location. The aerial system, receivers, central control position and the frequency-control system are described together with the requirements for, and techniques being used to obtain, radio channels of comparable quality to physical circuits.

INTRODUCTION

To meet the demand for long-distance overseas telephone and telegraph services in the post-war period the British Post Office opened a high-frequency (h.f.) radio receiving station at Bearley, near Stratford-upon-Avon, in 1953. The station was built on the site of a former airfield and, to provide services in the shortest possible time, existing temporary buildings were converted to house the equipment and to provide office and welfare accommodation. It was clear from the outset that these buildings could not be maintained indefinitely and that a new permanent building would be needed in due course. A new building on the same site was formally opened by Sir John Wall (Deputy Chairman, Post Office Board) on 23 November 1967 and is the first Post Office high-frequency receiving station to be centrally controlled. It has been designed so that it could be remotely controlled if this should prove operationally desirable.

The expanding network of submarine telephone-cable and satellite communication systems has already made an impact on the role of h.f. radio (Band 7, 3–30 MHz) as a medium for long-distance communication, and still further changes can be expected in the future. However, the use of h.f. radio will

maritime communications. The performance of h.f. radio circuits should conform, therefore, as closely as possible to standards obtainable from line circuits to permit their integration into switched networks in tandem with cable or satellite circuits. This involves the exploitation of all available techniques for combating the vagaries of the h.f. transmission medium, and the adoption of the most efficient operating methods. To this end the Post Office in 1966 opened a new transmitting station at Leafield¹ embodying the newest designs of radio equipment with a control system which, technically, is a major step forward towards unattended operation of high-power h.f. transmitting stations.

The need to rebuild the Bearley station presented a similar opportunity to modernize the receiving system by providing a central control position (C.C.P.), within the station, to control up to about 100 receivers. The control facilities have been restricted to those which would be both necessary and practicable at a remote point. When the original Bearley station was opened, radio-telephone traffic was already largely carried over independent sideband (i.s.b.) systems. However, radio-telegraph traffic in the early post-war era was, in the main, carried over single-channel circuits employing A1

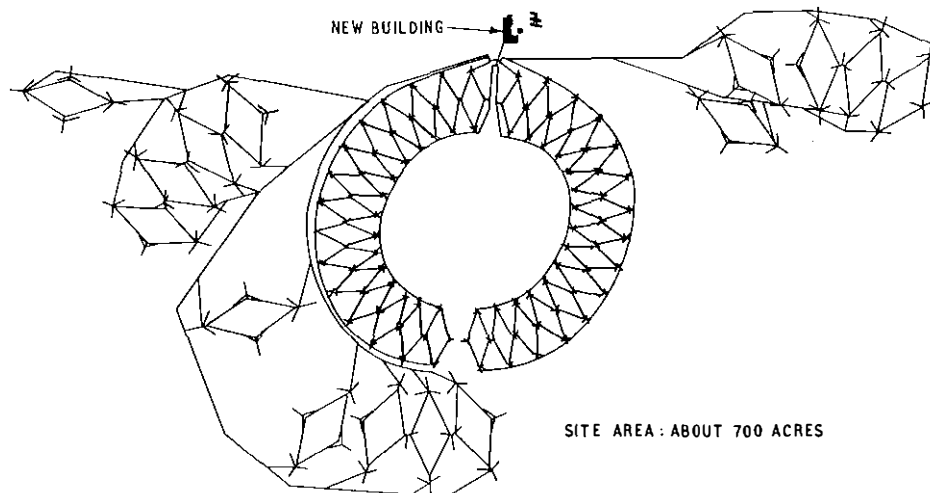


FIG. 1—Site and aerial plan

continue for as long as can be foreseen on lightly-loaded point-to-point routes, as back-up or spurs to cable and satellite systems, and for other specialized services such as

† Radio Planning and Provision (Overseas) Branch, Network Planning and Programming Department, Telecommunications Headquarters.

emissions (on-off keying) using the Morse code. The first post-war telegraph receivers were adaptations of war-time general-purpose designs, but notable changes in techniques and equipment were soon introduced. Firstly, high-speed A1 Morse services were increasingly replaced by frequency-shift (F1) unprotected radio-teleprinter links. These unprotected F1 circuits, although more resistant to fading and noise than

AI circuits, are still too susceptible to errors, resulting in the reproduction of incorrect teleprinter characters. Consequently, they are unsuitable for integration into a switched network such as that used for the telex service. The development of the synchronous 7-unit error-detecting code (ARQ),² the

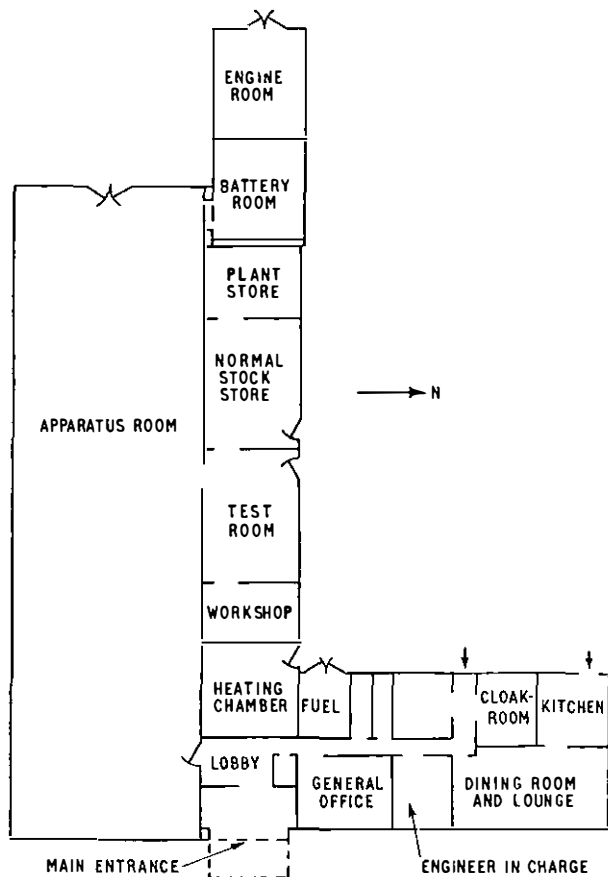


FIG. 2—Plan of new building

Thus, when it was necessary to move, the Bearley station was equipped with all the then current aids to efficient reception of telegraph traffic. Much of this equipment, although of valve design, was relatively new and, for economic reasons, had to be transferred to the new building. However, to meet the requirement for central control, automatically-tuned receivers, previously unknown in this class of equipment, were essential. The requirement was partly met by modifying some of the newer F1 telegraph receivers from the original station, but, in addition, a substantial number of new transistor-type i.s.b. receivers, designed to conform to a new British Post Office specification, were purchased.

Fig. 1 shows the layout of the aerial system and the buildings at Bearley. Fig. 2 shows the plan of the new building, and Fig. 3 shows the equipment layout in the apparatus room.

THE AERIAL SYSTEM

The original aerial system,⁴ which has been retained, consists of a ring of 30 double-ended 70 ft-high rhombics, and provides global coverage with spaced-aerial diversity reception. The ring provides an adequate performance above about 10 MHz, which is sufficient for many routes. Certain important routes, however, operate with frequencies down to 6 MHz or below and, for these, additional 150 ft-high rhombic aerials have been provided. The 150 ft aerials, in conjunction with the original ring, give a good overall performance between about 6 and 25 MHz and an acceptable performance over the entire usable h.f. spectrum.

Each rhombic-end is fed via a 600-ohm balanced overhead transmission line to a gantry close to the new building. At this point, connexion is made through a wideband impedance-matching transformer and a 75-ohm underground coaxial cable to the internal distribution board. In the old station, wideband distribution amplifiers were used to provide several substantially loss-free receiver outlets from each rhombic-end, but, as it had been found that intermodulation products in the amplifiers could seriously degrade signal-to-noise ratios by as much as 40 dB in certain conditions, wideband hybrid transformers are used to effect distribution within the new

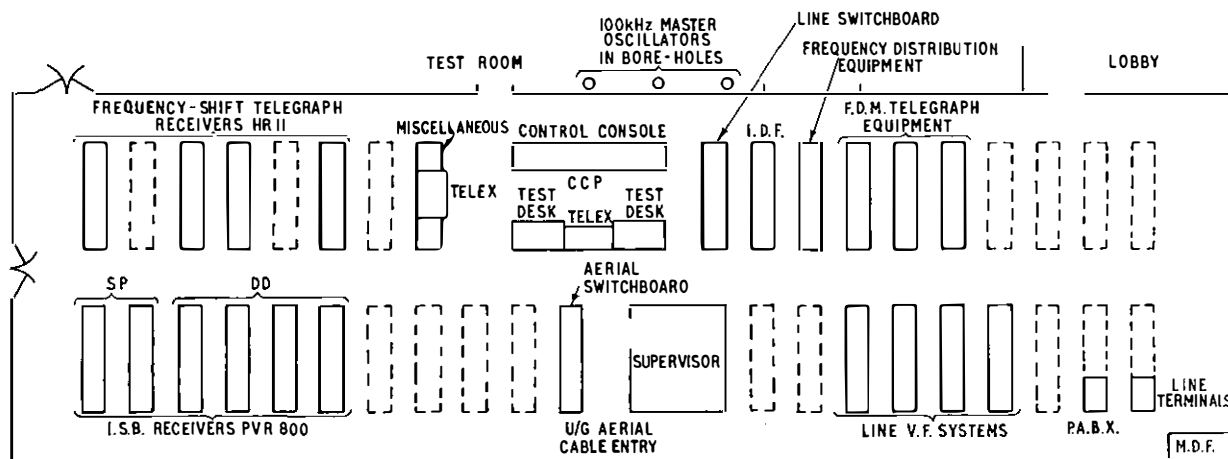


FIG. 3—Equipment layout in the apparatus room

system recommended by the C.C.I.R.,³ resulted in a radical overall improvement and, today, h.f. radio-telegraph circuits are comparable in reliability with line circuits. This important development further resulted in the more general use of i.s.b. multi-channel frequency-division telegraph systems, leading to more economic use of the h.f. spectrum and greatly increased traffic-handling capacity on radio-telegraph routes.

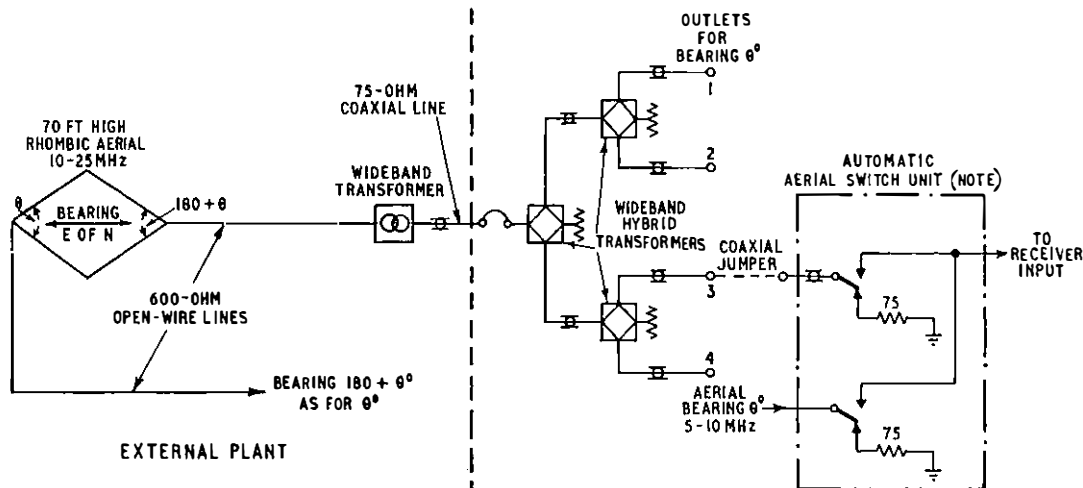
station. Four outlets are provided from each aerial connexion, the loss between the input and each outlet being approximately 7 dB. This loss has been partially offset at the higher frequencies by using low-loss cables between the gantry and the distribution board. The resultant overall performance-degradation is very much less than that introduced by amplifiers, the overall system noise factor being almost entirely

determined by route noise except occasionally at the higher frequencies.

The aerial outlets are connected to automatic aerial switches associated with the radio receiver. The reed-relay aerial switch enables any one of three aerials to be connected to a receiver as a function of the automatic tuning process. Unused outlets are terminated with 75 ohms to preserve the correct hybrid matching. Fig. 4 shows the normal arrangement.

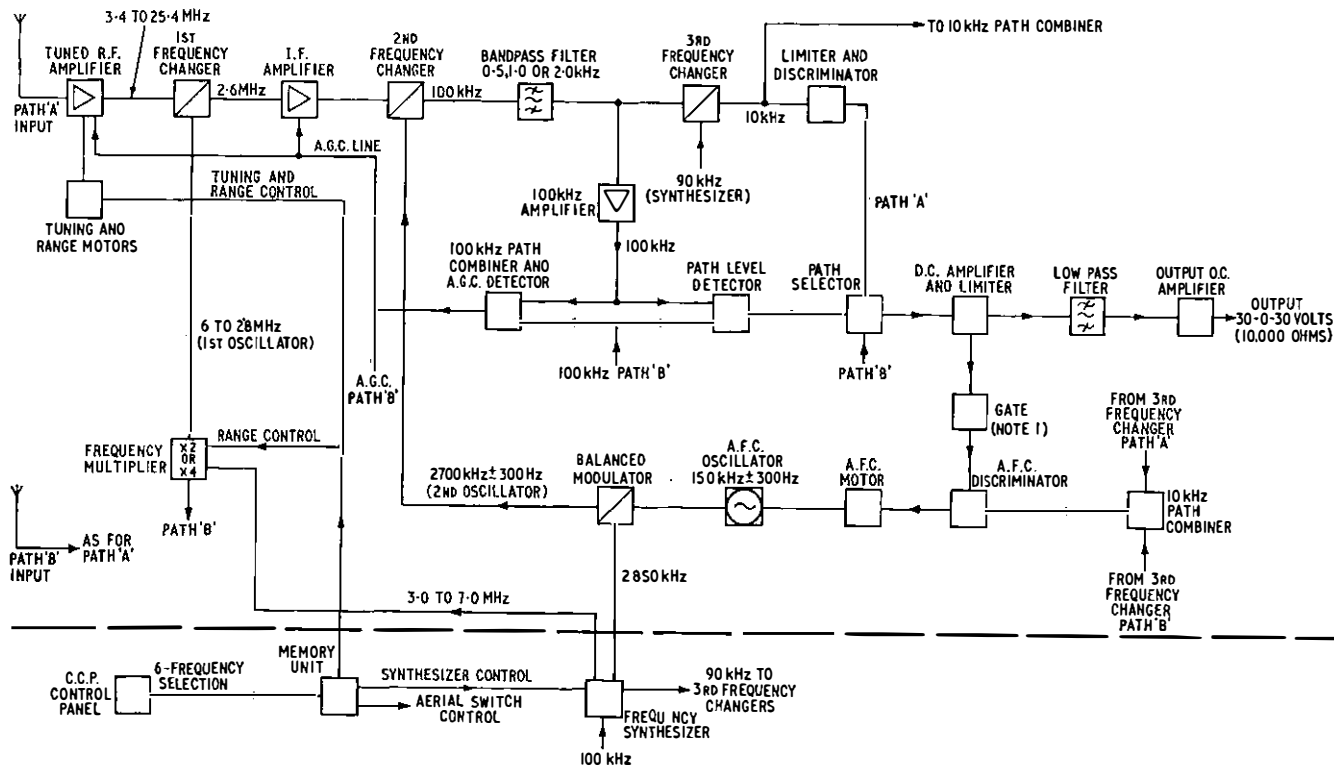
dual-diversity receiver is suitable for the reception of an F1 emission at speeds up to 200 bauds, which, with time-division techniques, can carry four 50-baud teleprinter channels. Alternatively, and with additional equipment, the receiver can be used for four-frequency duplex (F6)⁵ reception.

The HR11 receivers were modified prior to transfer to permit their operation from the C.C.P. Briefly, the modifications consisted of providing motor control of the tuned radio-frequency (r.f.) amplifiers and of the frequency-range



Note: Duplicates for dual-diversity receivers

FIG. 4—Aerial-distribution system



Note: The gate permits the a.f.c. discriminator to operate on either the mark or space frequency

FIG. 5—Marconi HR11 frequency-shift telegraph receiver modified for C.C.P. operation

RADIO RECEIVERS Frequency-Shift Telegraph Receivers

Twenty, valve-type, F1 telegraph receivers (Marconi HR11) were transferred from the original station to provide services on routes requiring only a small number of circuits. The HR11

switches, to give automatic selection of any one of six pre-set frequencies. The first beating oscillator has been replaced by an external frequency synthesizer capable of generating frequencies which reflect the accuracy of the stable reference-frequency source available at the station. The second beating

oscillator, to which automatic frequency correction (a.f.c.) is applied, has been stabilized by combining a secondary output from the synthesizer at 2,850 kHz with a 150 kHz variable-frequency oscillator to produce the required nominal frequency of 2,700 kHz. The frequency of the 150 kHz oscillator is varied by a motor-operated capacitor controlled from the a.f.c. discriminator. Fig. 5 shows a block schematic diagram of the modified receiver.

I.S.B. Receivers

Thirty-six new i.s.b. receivers are available for the reception of four-channel telephone and multi-channel telegraph services. The 12 telephony receivers are single-path (non-diversity) types because, so far, spaced-aerial diversity has proved to be of little advantage for this type of service; the 24 dual-diversity receivers are of the same basic design. All 36 receivers were supplied by The Plessey Co., Ltd., against a British Post Office performance specification.

This receiver, with the maker's code PVR800, contains many novel design features; it has been described in detail in a recent article in this Journal⁶ and only a brief outline is given here. A simplified block diagram is shown in Fig. 6. The receiver is a quadruple superheterodyne with a first intermediate frequency (i.f.) above the upper limit (27.5 MHz)

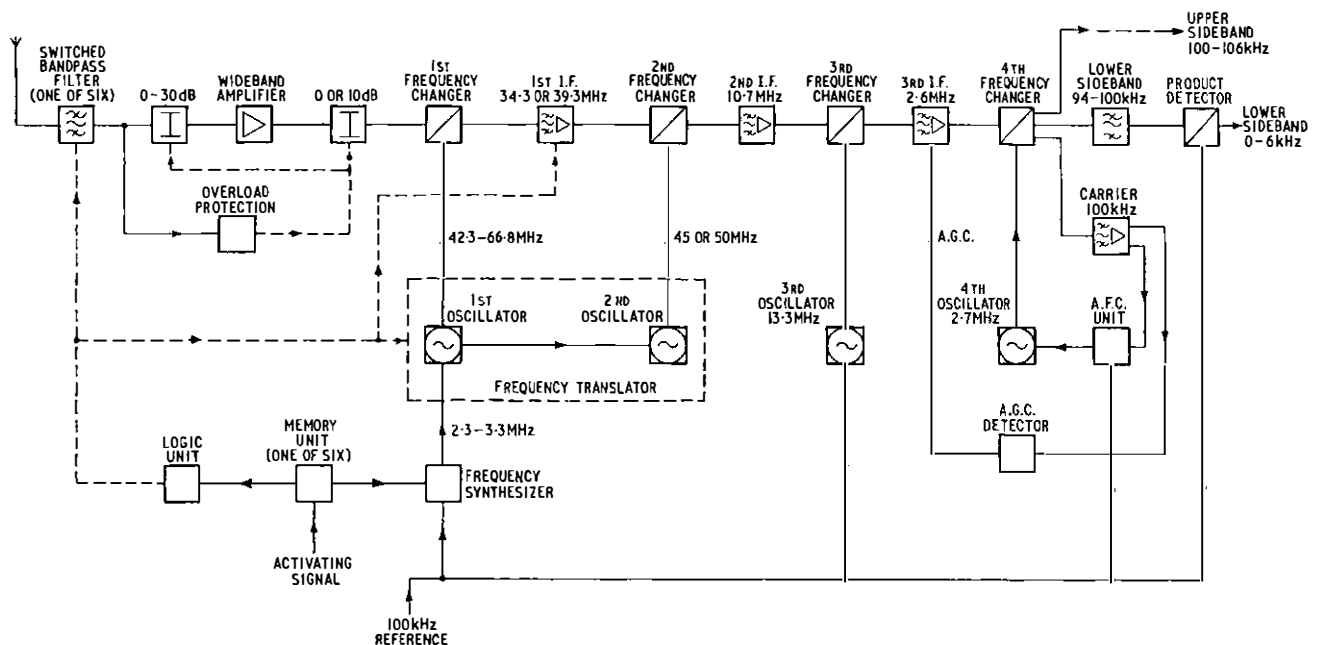


FIG. 6—Simplified block schematic diagram of PVR800 receiver

of the tuning range. Subsequent i.f.s are at 10.7, 2.6 and 0.1 MHz, sideband separation being effected at the last frequency. Tuning is effected by activating one of six pre-set memory units, each of which is adjustable, in terms of input-signal frequency, over the range 3 to 27.5 MHz; the minimum tuning step is 125 Hz. The memory, with an associated logic unit, causes the inbuilt frequency synthesizer to produce the correct first-oscillator frequency, and controls the selection of the appropriate r.f. input band-pass filter. The tuning is then swept, by automatic control of the fourth oscillator frequency (nominally 2.7 MHz), over a range of ± 300 Hz about the selected tune-frequency. The automatic search continues until a carrier, with a signal-to-noise ratio better than 7 dB, appears in the carrier-filter pass-band; alternatively, if no signal is found after 30 minutes, the search ceases. If, however, a carrier is found within the restricted

search range there is a high probability that it is the wanted transmission and a visual signal at the control point shows that the receiver is in tune. Correct tuning is then maintained, despite permissible frequency variations from the distant transmitter, by a.f.c. action.

RECEIVING SYSTEMS

Telephony Circuits

An incoming h.f. i.s.b. telephone transmission may comprise up to four channels, two in each 6 kHz-wide sideband, one channel in each sideband being displaced at audio frequency to the band 3-6 kHz before combination with the other channel and application to the radio transmitter. At the receiver, each sideband is converted to a 0-6 kHz baseband for onward transmission by line to the London Radio-Telephone Terminal (RTT)⁷ where, after channel processing, the circuits are extended to the International Exchange for the switching of calls to the inland network or to other overseas circuits.

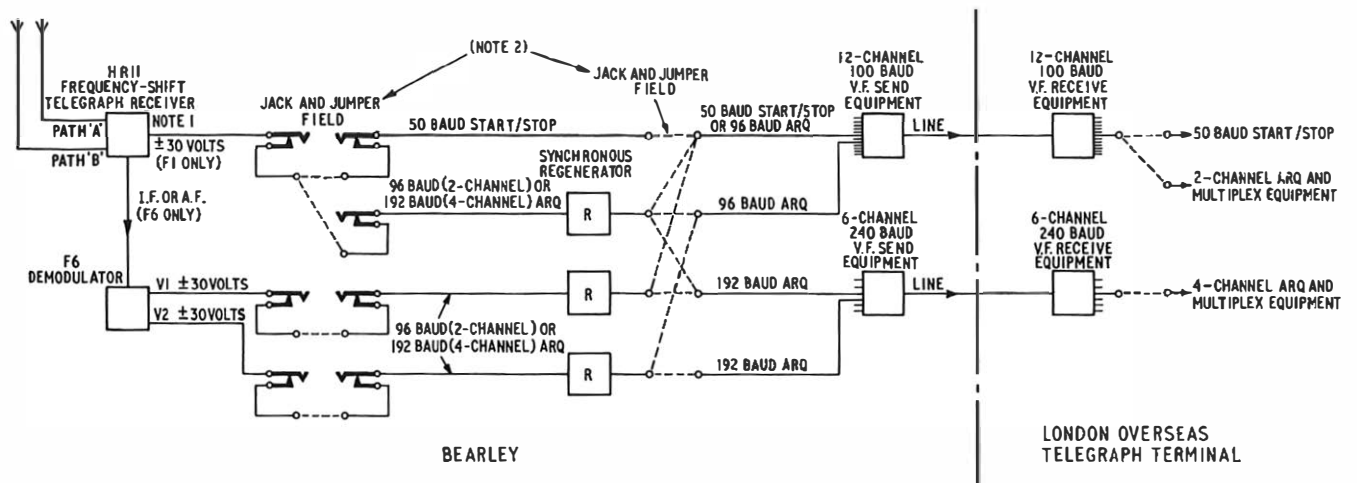
Telegraphy Circuits

Fig. 7(a) and (b) show the outlines of two typical telegraph receiving systems. In Fig. 7(a) the combination of signals

from the A and B diversity paths is made in the radio receiver. For start-stop, 50-baud F1 (or F6) channels the output of the receiver is connected directly to the input of a unidirectional multi-channel voice-frequency (m.c.v.f.) system for transmission to the London traffic terminal. For synchronous F1 (or F6) channels working at 96 or 192 bauds the signals are regenerated before transmission to London.

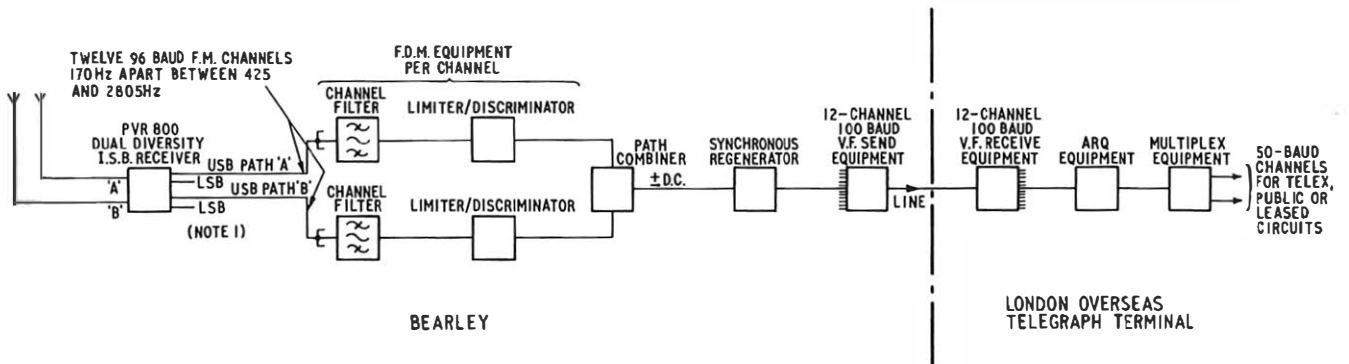
Fig. 7(b) shows the arrangement for i.s.b. multi-channel telegraph systems. The audio-frequency outputs from the two paths of the radio receiver contain similar channel-aggregate signals which are applied to frequency-division multiplex (f.d.m.) equipment to separate the channels, demodulate them and combine the two diversity paths.

The main types of f.d.m. equipment in use have been described in detail and compared elsewhere,⁸ but their main characteristics are summarized here for convenience. A six-



Notes: 1. The receiver may be used for F1 or F6 with additional demodulator.
 2. The alternative connexions shown are selected according to service requirements. Jacks provide rapid flexibility in an emergency.

(a)—Frequency-Shift System



Note: Arrangement shows 12 channels in upper side-band (u.s.b.). Traffic capacity can be doubled by similar use of lower side-band (l.s.b.)

(b)—I.S.B. Multi-Channel System

FIG. 7—Typical telegraph receiving systems

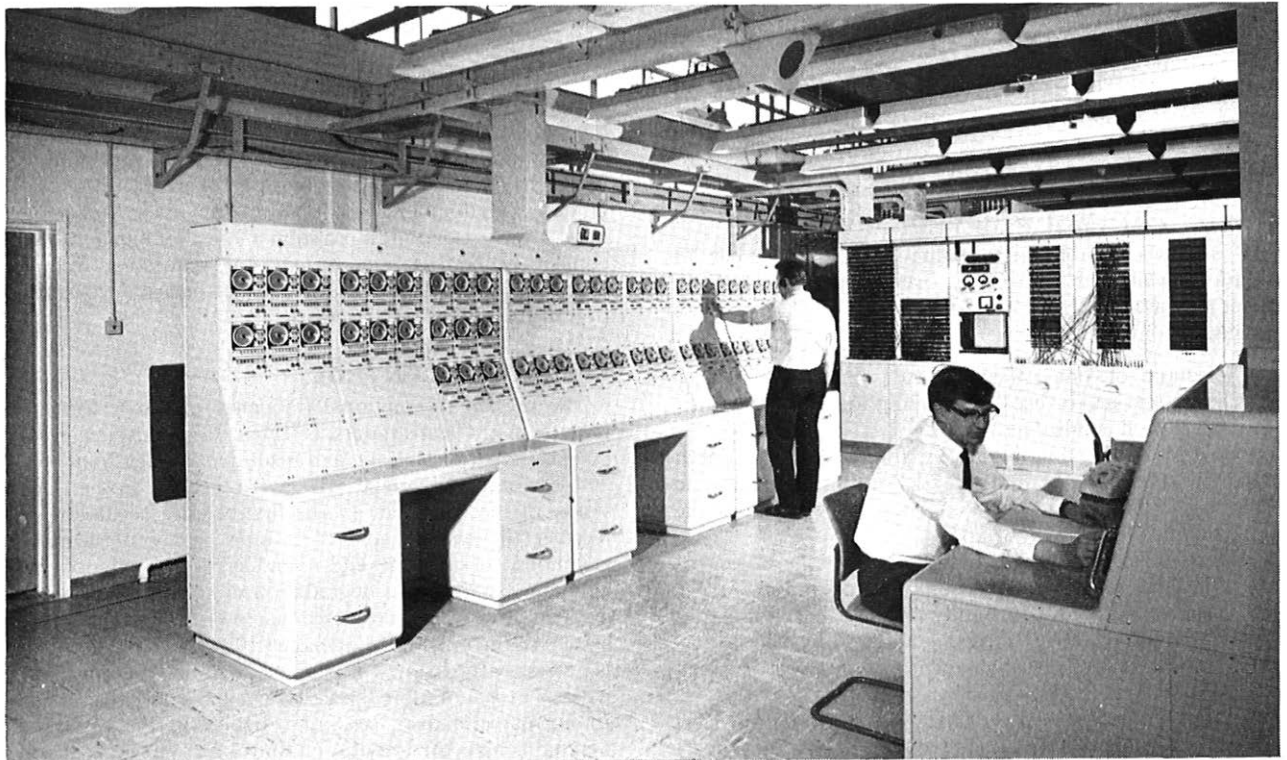


FIG. 8—Central control position



FIG. 9—Control panel

channel system in which each channel utilizes two tones, spaced apart by a multiple of 170 Hz and amplitude-modulated in antiphase (normally at a rate of 96 bauds but exceptionally at 192 bauds), is being superseded by a 12-channel system in which each channel is frequency modulated (deviation ± 42.5 Hz, inter-channel spacing 170 Hz) at rates up to 100 bauds. The latter system can give twice the traffic capacity (at 96 bauds) of the former for a given bandwidth. An i.s.b. radio-telegraph link using 3 kHz of bandwidth and 12 96-baud channels in each direction has a capacity of 24 50-baud circuits; further capacity can be added to any route, provided spectrum space is available, by multiplexing the f.d.m. systems.

CENTRAL CONTROL POSITION

Fig. 8 shows a photograph of the C.C.P., which has an ultimate capacity for controlling over 100 receivers. Each receiver has an associated control panel (Fig. 9) giving the following main facilities.

(a) Selection of one of six predetermined frequencies assigned to a service, for use in prevailing long-term or short-term propagation conditions.

(b) Restart of the automatic search process; the search is normally started by the frequency-selection but it has to be re-started if the wanted signal does not appear within the first 30 minutes.

(c) Lamp indication of a.f.c. inhibition when the carrier-to-noise ratio falls below 7 dB (PVR800 receivers only).

(d) Disablement of a.f.c. action to improve reception under marginal conditions (HR11 receivers only).

(e) Lamp indication of tuning completion; this is given when the a.f.c. system has locked-on to a carrier.

(f) Lamp indication of diversity failure if the output level from one path should differ appreciably and continuously from the other path level (e.g. aerial failure or a fault in one path of the radio receiver).

(g) A chart record of received field strength and, where appropriate, telegraph distortion.

(h) Headphone jacks for signal identification purposes and for aural supervision during or after tuning.

The field strength and telegraphic error-rate, item (g), need to be displayed continuously at the control point as an indication of circuit merit.⁹ Field strength alone is not a sufficient indication of telegraph-circuit reliability; indeed a low field strength is generally accompanied by reduced multipath propagation and can give a better traffic efficiency than a strong signal, provided that the signal-to-noise ratio is adequate. Similarly, error-rate is not, by itself, sufficient because a high error-rate can arise from interference or other causes. Taken together, however, low and decreasing field strength accompanied by an increasing error-rate is indicative of an impending fade-out.

The error-rate record could have been derived from the ARQ terminal in London, but this may be ambiguous because it is difficult to derive error pulses which are indicative solely of the conditions on the incoming path. Also the record would be restricted to use on ARQ-protected channels. Instead, a local telegraph monitor is used for one channel on each route to give a pilot indication of distortion exceeding a predetermined value (e.g. 25 per cent). The indications become more frequent as the average signal-to-noise ratio decreases below a certain critical value, and by measuring their incidence-rate a significant record of error-liability is produced. This, in conjunction with the field-strength information gives, typically, some 30 minutes fade-out warning and allows time to request a frequency-change at the distant end before communication fails.

Because of the large number of recorders required, a cyclogram recorder which gives a continuous 2-hour trace on a circular chart was chosen. The parameters are recorded alternately by the single stylus, the traces being erased continuously and the chart used over and over again.

As the station cannot be restricted to carrying services where the technical and operational standards at the distant transmitting stations are invariably high, facilities are available at test desks, near to the C.C.P., to enable faulty transmissions to be analysed. This allows any receiver output to be selected, and telegraph transmissions to be broken down into channel components, for checking level, distortion, or other parameters. Telephone speaker circuits to the London radio-telephone and radio-telegraph terminals also terminate at the test desks.

There are also two telex stations at the C.C.P. One, connected to the local telex exchange, is for general-purpose and United Kingdom inter-station use; the other, directly connected to the London International Telex exchange, is used to contact overseas terminals (e.g. for requesting frequency-changes), and avoids the possibility of delays due to congestion in the inland telex network.

FREQUENCY CONTROL

The present international frequency tolerance for band 7 point-to-point transmitters is 15 in 10^6 ; thus, an error of 300 Hz is permissible in a transmitted carrier frequency at 20 MHz, and if a similar error were to exist, in the opposite sense, in the frequency of the first-beating oscillator in the receiver the end-to-end error would be about 600 Hz. For telephone services the end-to-end error should not exceed about 20 Hz if serious degradation of speech quality is to be avoided. For the widely-used narrow-shift f.d.m. telegraph system the error should not exceed 10 Hz. Even tighter control is necessary for the new Lincompex¹⁰ radio-telephone system, where an error of more than 2 Hz can have undesirable effects. In normal circumstances, a.f.c. action in the receiver will maintain the error to within about 2 Hz, but a.f.c. forms an appreciable part of the cost of the receiver and may sometimes be rendered ineffective by interference in the carrier channel.

There is much to be said for maintaining transmitter frequencies and receiver-oscillator frequencies to within, say, 1 Hz of their nominal values and dispensing with a.f.c. This will become increasingly practicable as distant administrations realize the other advantages (e.g. flexibility) of frequency synthesis for generating carrier and conversion frequencies.

Despite the present need for a.f.c. to compensate for inaccuracies and variations in the frequencies of most distant transmitters, the stabilization of receiver first-oscillator frequencies is an important factor in the success of C.C.P. control at Bearley. These frequencies are accurate to within 1 in 10^7 and this effectively limits the receiver automatic search-range to that governed by the international frequency tolerance for transmitters. A wider search, which would be necessary if the receiver a.f.c. system had to compensate for significant errors in the first-oscillator frequency, would greatly increase the risk of locking-on to a wrong signal, such as a close-in sideband component of a multi-channel telegraph transmission, instead of the carrier.

The frequency synthesizers used in the Bearley receivers for producing the adjustable first-oscillator frequencies, and other fixed conversion frequencies, reflect the accuracy of a central 100 kHz crystal-controlled master-oscillator system which is identical in design to that at the Leaffield transmitting station.¹ The source accuracy is maintained to within 1 in 10^7 of the nominal value by adjustments to the master-oscillators (using a standard frequency transmission for comparison) about once in 12 months. Accuracy could be maintained to within 1 in 10^8 , with more frequent adjustments, if future developments should make this necessary.

POWER SUPPLIES

Much of the equipment transferred from the original building is mains-operated, but this will be replaced by transistor-type equivalents in due course. However, the new i.s.b. receivers, the regenerative repeaters and other transistor-type equipments operate from central, float-charged, high-performance secondary-battery installations. There are three supplies, viz:

- (i) —24 volts (nominal), with 1-hour reserve at 360 amperes, for transmission equipment (the maximum demand for 100 receivers and ancillary equipments would be of the order of 300 amperes),
- (ii) 12–0–12 volts (nominal), with 1-hour reserve at 75 amperes, for signalling equipment, and
- (iii) —50 volts (nominal), with 1-hour reserve at 120 amperes, for relay operation.

Under normal conditions the battery voltages are some 16 per cent above the nominal values. Voltage regulators are therefore fitted, where necessary, to maintain supplies to within specified limits. Distribution to the equipment suites is made via aluminium busbars, with a cross-sectional area of 2 in² (24-volt supply), running the whole length of the apparatus room with feeds teed-off to fused distribution units at the ends of individual suites.

The power consumption of the PVR800 receivers and other transistor-type equipments, which carry the major portion of the traffic passing through the station, is only about 2 kW.

The HR11 receivers, the v.f. line systems and other valve-type equipments draw some 20 kW. The estimated load for a full complement of transistor equipment is about 6 kW, which is less than the present full lighting load.

A 47 KVA prime-mover stand-by plant, controllable from the C.C.P., can be brought into operation in the event of a prolonged mains failure.

CONCLUSION

Experience of operating the new Bearley receiving station by central control indicates that, from a technical aspect, the station could be remotely operated. For this all emissions should be consistently maintained to a high standard, especially as regards accuracy and stability of frequencies, correct carrier-to-sideband power ratios, and freedom from spurious radiations. Reserve facilities would also be required to take over services at short notice in the event of emissions temporarily falling below the required standard or in the event of a station fault. At present, overseas standards are not, universally, sufficiently high to permit remote control. Moreover, the problem of split control has to be resolved, i.e. more than one traffic terminal may be served by a composite telephone-telegraph link or a multi-channel telegraph service may carry both telex and public (or leased) circuits.

Nevertheless, the new station, even if fully equipped with 100 receivers, could probably be operated with two men per shift, compared with about five times that number for an equal complement of manually-tuned receivers. This considerable gain in productivity is, in itself, a measure of the success of the project.

ACKNOWLEDGEMENTS

Acknowledgement is made to The Plessey Co., Ltd., for the use of the photograph shown in Fig. 8.

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A Double-Triangular Type Frame and Cover for Carriageway Jointing Chambers

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U.D.C. 624.027.8: 621.315.233

A variety of designs of frames and covers has been used to provide access to carriageway jointing chambers. A new design of cover has now been developed in an effort to eliminate the disadvantages of earlier designs.

INTRODUCTION

Throughout the history of underground construction in the Post Office, the need to provide access to jointing chambers for the purposes of maintenance and alterations of the cable networks has been met by a variety of designs of frames and covers. Each type of frame and cover employed has, however, been found to have its own disadvantages. The specially-designed Frame and Cover, Unit Type,¹ for example, which is the current standard, suffers from rocking and from frame failure at the joints, unless particular care is taken during installation. Search for an improved frame and cover included trials of a double-triangular type of American origin, which gave encouraging results. This led to a new design of cover² which has now been introduced as an alternative to the unit-type frame and cover, and it seems likely that it will eventually become the British Post Office standard.

DESIGN CONSIDERATIONS

An ideal frame and cover should satisfy the following requirements.

(i) It must withstand the highest loads to which it is likely to be subjected.

(ii) The cover must not be free to move relative to the frame, as rapid wear of the rubbing surfaces can result. This movement usually takes the form of the cover rocking, sliding or bouncing when a vehicle passes over it.

(iii) The frame should be made in one piece. Experience has shown that many failures in the current Post Office type can be attributed to a sectionalized frame.

(iv) The design should avoid lengthy machining operations that make the item costly to manufacture.

(v) The weight of the cover should be kept to a minimum to simplify lifting.

(vi) It should not be possible for the cover to fall through the frame opening into the jointing chamber.

(vii) It should be possible to install the frame with the covers removed.

SINGLE-UNIT DOUBLE-TRIANGULAR MANHOLE COVER

Trials of the original American design of frame and cover, supplied by manufacturers in this country, indicated that this type of cover fulfilled most of the above requirements, but a small percentage of the covers fractured in service. This weakness was overcome by modifying the web structure of the cover so that its strength was substantially increased with a negligible increase in weight.

† Civil and Mechanical Engineering Branch, Telecommunications Development Department, Telecommunications Headquarters.

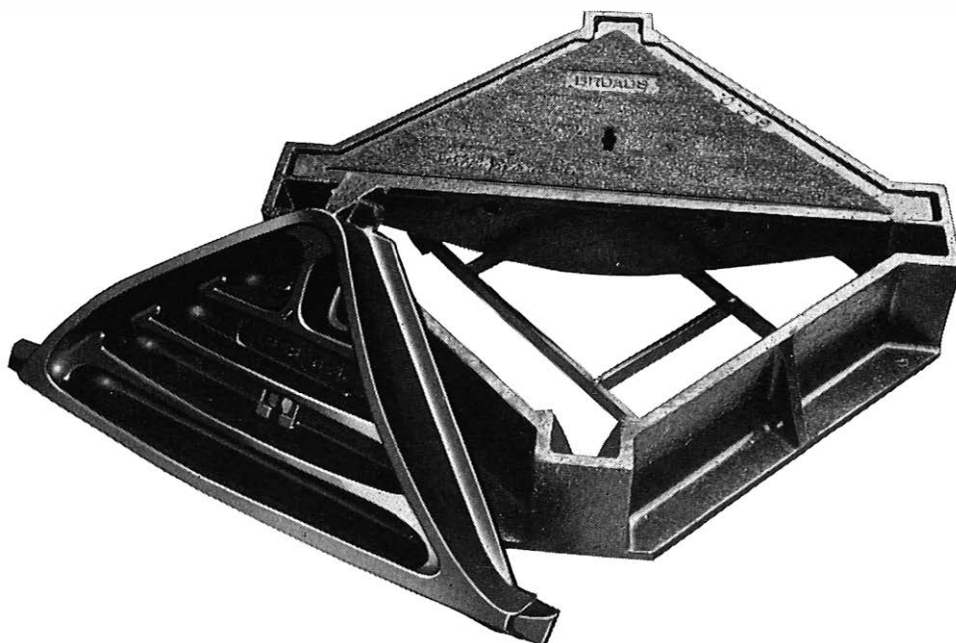


FIG. 1—Frame and triangular half-covers

The double-triangular frame and cover comprises a one-piece cast-iron frame into which are fitted two triangular half-covers, also of cast-iron, and a removable mild-steel safety grid (Fig. 1). Each half-cover is supported in the frame by three lugs, and is thus stabilized and non-rocking. Each supporting lug projects beyond its respective corner of the triangle, and any tipping action from traffic loading applied to the extreme edges of the cover is thus eliminated. The lugs are wedge-shaped, and a mating taper in the frame creates a gripping action sufficient to resist bounce of the cover, but

with the road surface. When road closure overnight is undesirable, resin mortar may be used in lieu of cement mortar so that the installation may be re-opened to traffic the same day.

MULTIPLE-UNITS FOR CARRIAGE-WAY JOINT BOXES

Two-cover and three-cover units using the same basic principles as the single-cover unit are being developed for use on joint boxes; Fig. 2 illustrates the two-cover unit. With

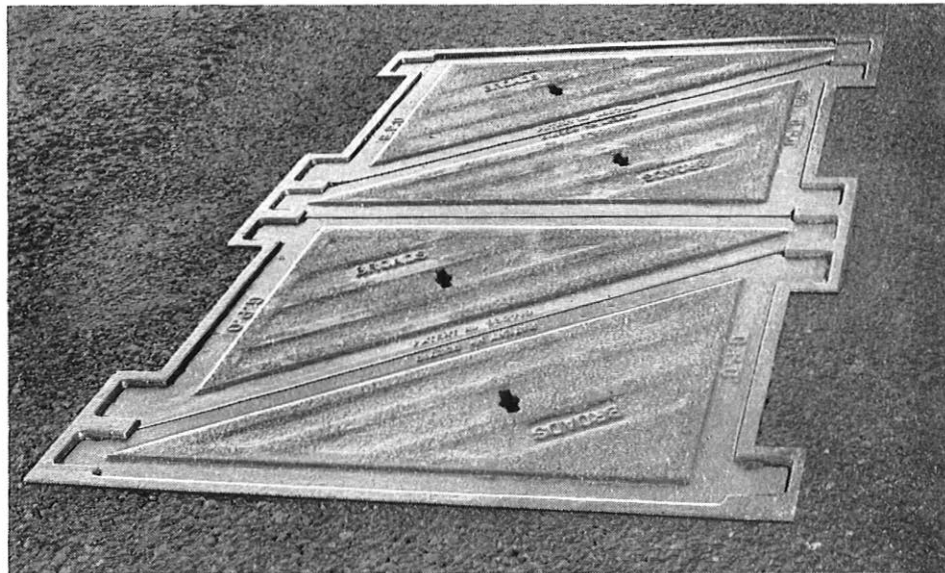


FIG. 2—Two-cover unit

the cover can be readily freed for lifting by striking the lugs with a piece of timber.

The frame chosen for Post Office use is 6 in. deep, and has a 2 ft square clear opening. It weighs 196 lb, and, to facilitate handling with lifting equipment, four lifting holes are provided in the frame webs. Each half-cover weighs 140 lb and can be lifted by means of a single key-hole sited above the centre of gravity. The removable safety-grid is provided to safeguard cables, etc., in the event of a cover being accidentally dropped into the opening. The upper surface of the cover is treated with a non-skid coating of epoxy resin and calcined-bauxite chippings.

RESULTS OF TRIALS

Trials of new covers of the improved design were carried out and, to date, none of these has failed. The load test specified in BS 497³ for Grade A covers calls for the application of a 35-ton load via a 12 in. diameter disk at the centre of the cover for a period of 30 seconds without fracture. The modified design adequately meets this specification when the test load is placed on the centre of each half cover, and tests on six half-covers produced an average result of 43 tons.

INSTALLATION

Installation is extremely simple. The covers are taken out of the frame, and the frame is then set on to a bed of cement mortar and gently tapped down until the top edge is level

these, however, there are a number of additional difficulties to be overcome, and a small quantity is currently undergoing a field trial to provide further information.

CONCLUSIONS

The double-triangular type of frame and cover theoretically satisfies most of the ideal requirements, and the reaction of users has been favourable. If it proves to be as successful in a multiple form, as indications show the single unit to be, considerable savings should be possible due to the lower initial outlay and installation costs, and also the longer life that can be expected.

ACKNOWLEDGMENT

Acknowledgment is made to the Telecommunications Region and Area staffs who assisted in arranging the trial installations, and also to Broads Manufacturing Company, Ltd., for their co-operation with the experimental modifications.

References

- ¹ JENNINGS, S. W., and HEARN, A. F. L. A New Frame and Cover for Carriageway Manholes and Joint Boxes. *P.O.E.E.J.*, Vol. 54, p. 164, Oct. 1961.
- ² The design is the subject of Patent No. 932719.
- ³ B.S. 497:1967. Specification for Cast Manhole Covers, Road Gully Gratings and Frames for Drainage Purposes.

A New Lamp-Signalling Cord P.M.B.X.— Switchboard, P.M.B.X., No. 4/1A

D. C. JONES and V. B. CROUDACE†

U.D.C. 621.395.23

The new range of modern private manual branch exchanges, which has so far included three desk-mounted cordless switchboards, has now been extended by the introduction of a new cord-type, floor-pattern switchboard. It is a lamp-signalling switchboard incorporating novel electrical and constructional features, and has a capacity for 160 extensions when used as a single position and for 200 extensions when multiplied. Its 50-volt d.c. power supply is normally derived from a separate mains-driven power unit. The new P.M.B.X. is suitable for connexion to all types of exchange except magneto.

INTRODUCTION

Switchboard, P.M.B.X., No. 4/1A has been designed to replace existing types of switchboards of the following sizes: 10 + 30, 10 + 50 and 10 + 60. When multiplied, it is intended to supersede double 10 + 50 switchboards and P.M.B.X.s No. 1 up to a capacity of 40 exchange lines, 10 private circuits and 200 extensions. The use of a 2-panel repetition for the multiple means that an installation can grow from a single position to a multiple suite, up to a maximum of four positions, with each operator having access to all lines on her own position. An installation is, in general, referred to simply as a "P.M.B.X. No. 4."

The switchboard is of a modern appearance approved by the Council of Industrial Design, and, in its standard colour scheme of 2-tone grey, matches other new items of subscribers' apparatus and harmonizes with modern office fittings and furnishings. Great attention has been paid to detail, as exemplified by such things as the use of nickel-silver bushes for jacks, white brass (i.e. brass with a 7 per cent content of nickel silver) for plugs, chrome finish for designation strips, and plug sleeves coloured light French grey. Extensive use has been made of laminated plastics for cladding.

The switchboard accommodates much of the equipment required for a complete installation, but the power unit, ringer, and signalling and distribution units are mounted externally. Extension circuits are 2-wire, with earth-loop recall.

FACILITIES PROVIDED

The main facilities provided by the switchboard are as follows.

- (a) Lamp signalling throughout.
- (b) Transmission power feed from the main exchange on extension-to-exchange calls.
- (c) Double clear on extension-to-exchange calls.
- (d) Follow-on call-trap on incoming exchange calls.
- (e) Automatic holding of exchange calls.
- (f) Divided power feed on extension-to-extension calls.
- (g) Individual supervision on extension-to-extension calls.
- (h) Through dialling and clearing from extensions.
- (i) Press-button recall on extension and exchange calls.
- (j) Jacks suitable for private and inter-P.B.X. circuits.

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(k) A transmission and signalling limit of 500 ohms for extension circuits, and 920 ohms for exchange-to-extension connexions when connected to an exchange equipped for 1,000-ohm lines.

(l) Sidetone suppression and automatic control of received speech level in the operator's circuit. The operator's instrument can be either a headset or a handset, with, if required, a transmitter cut-out key.

(m) In the event of mains failure, exchange-to-extension calls are maintained, the operator can answer and originate exchange calls, and a non-locked calling signal is given on the exchange-line lamps.

(n) "Click" engaged-test on multiple installations.

(o) Automatic ringing of extensions from calling cords.

(p) Position coupling on multiple installations.

(q) Subscriber-controlled night busy of P.B.X.-group exchange lines where the main exchange is suitably equipped.

(r) Audible signal for use with double clear.

(s) Duplicate calling appearances on extension circuits on multiple installations.

(t) Ancillary calling appearances of exchange and inter-P.B.X. circuits on multiple installations.

(u) Free-line signalling on exchange and inter-P.B.X. circuits on multiple installations.

(v) Subscribers' private metering.

It should be noted that items (r) to (v) are added when required. In addition, means have been provided to facilitate the connexion of a keysender when suitable equipment becomes available.

PHYSICAL DESIGN

The Switchboard, P.M.B.X., No. 4/1A (Fig. 1) is constructed with a metal framework and plastic-faced panels. To permit the passage of the switchboard into premises with narrow doorways the desk in front of the keyshelf can be lowered through 90° to reduce the overall depth of the switchboard to 27½ in. (Fig. 2). In the assembly of a multiple suite the unwanted side panels are removed and adjacent switchboards are bolted together. The top and rear panels are readily removable for access to the equipment within.

The circuit and lamp jacks are of a new design comprising individual moulded units mounted in strips of 10 or 20 as required, thus permitting the replacement of single jacks. All circuit designations appear on the relative lamp opals, and these are mounted on metal strips that can readily be removed from the front of the switchboard to facilitate

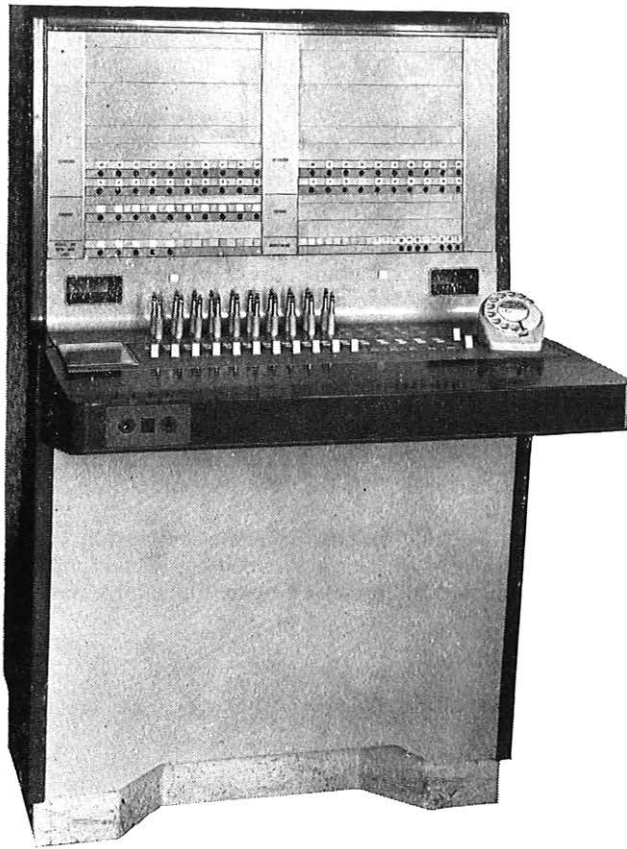


FIG. 1—Switchboard, P.M.B.X., No. 4/1A

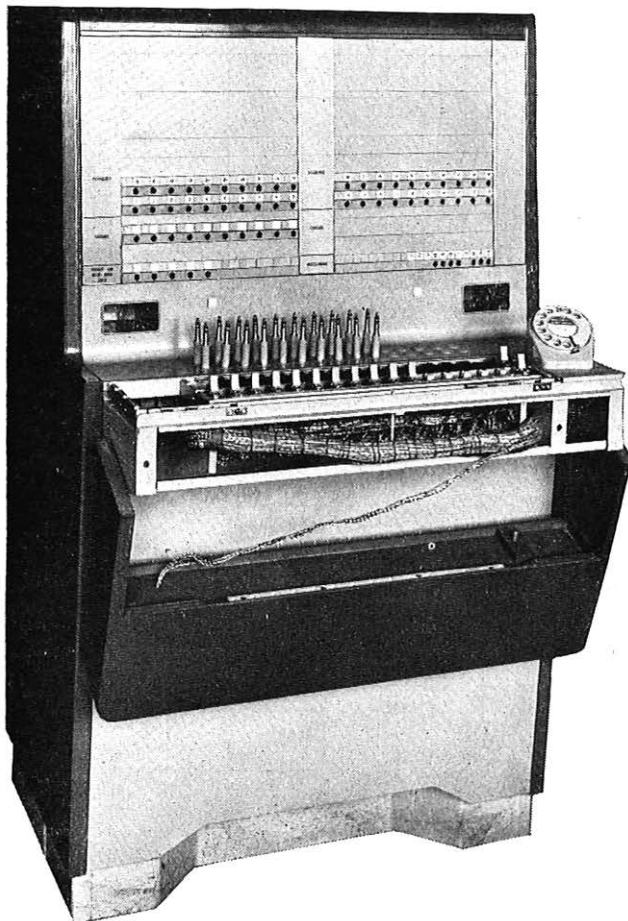


FIG. 2—Switchboard with desk lowered

changing the lamps. The designation strips are simply clipped in so that they too can be easily removed and the designation labels changed when required.

The key-plate cover has a quick-release feature, and, when the cover has been removed, the key-frame assembly, which is hinged, can be raised to give access to the key and lamp wiring (Fig. 3). When cord-circuit metering is required an

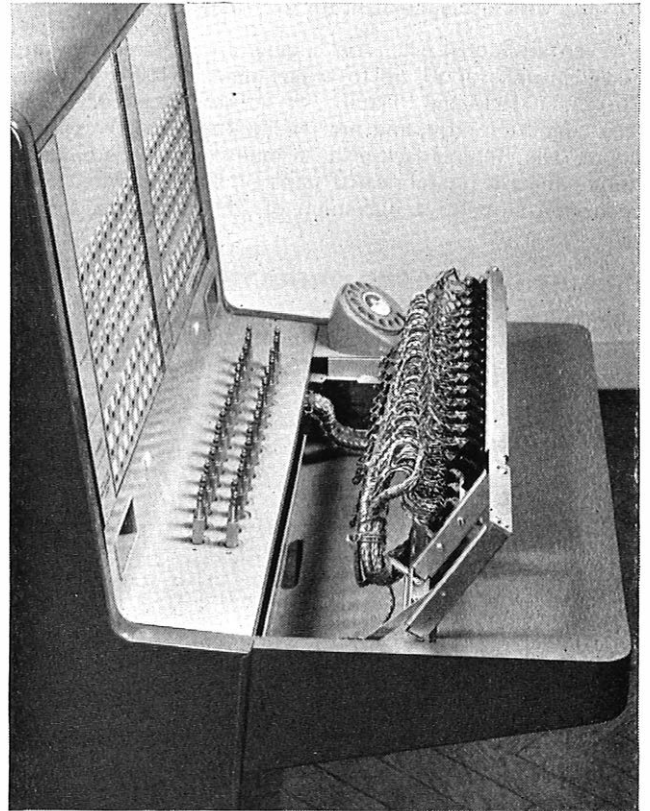


FIG. 3—Switchboard with keyshelf raised

alternative form of key-plate cover, with windows and cut-outs to enable the meters to be read and reset, can be fitted.

The switchboard is supplied fitted with 10 pairs of cords, out of a total capacity of 15, but the full quota of cord-circuit keys is provided, with those for circuits 11-15 retained out of sight below the key-plate cover until required to be brought into use.

A new type of quick-release dial mounting is used, and two operator's instrument jacks are provided; a switch can be fitted to give transmitter cut-out facilities. Two ticket boxes and a notice frame are provided, and a miscellaneous jack-and-lamp strip accommodates switchboard alarms, hold jacks and cord-test jacks.

The relay-sets for the exchange lines, cord circuits and operator's circuit are of the strip-mounted, jack-in type, all of which can be accommodated within the switchboard, with the exception of exchange-line relay-sets in excess of 12. Cord-circuit relay-sets having either one or two circuits per plate, and exchange-line relay-sets having either two or three circuits per plate, are held in stock, so enabling equipment provision to be economically matched to circuit requirements.

At the base of the switchboard are connexion strips for exchange-line circuits and the connexion of externally-mounted apparatus, and a holder for a small reserve battery, which is required to maintain certain facilities under conditions of mains failures. Cable entry to the switchboard is via three holes in the base, one on either side and one in the rear, or, if underfloor chases are available, directly into the bottom.

At the top of the switchboard is a 32-way fuse mounting,

for the distribution of the 50-volt d.c. supply, and connexion strips for extension circuits.

A Switchboard, P.M.B.X., No. 4/1 A, as stocked, is equipped to the following extent.

- (i) Extensions: wiring and face equipment for 40 circuits.
- (ii) Exchange lines: wiring for 20 jacks with face equipment for 10 circuits.
- (iii) Inter-P.B.X. lines or private circuits: wiring for 10 jacks with face equipment for five circuits.

When additional extension circuits are required they are added in units of 10, up to a maximum of 160 extensions. Strips of 10 jacks and 10 lamp jacks are stocked already wired to a connexion strip, and are readily fitted into the switchboard. The multiple jack-field on multiple suites is built up using similarly pre-fabricated units of 20 jacks wired to a connexion strip, to a maximum of 200 extensions.

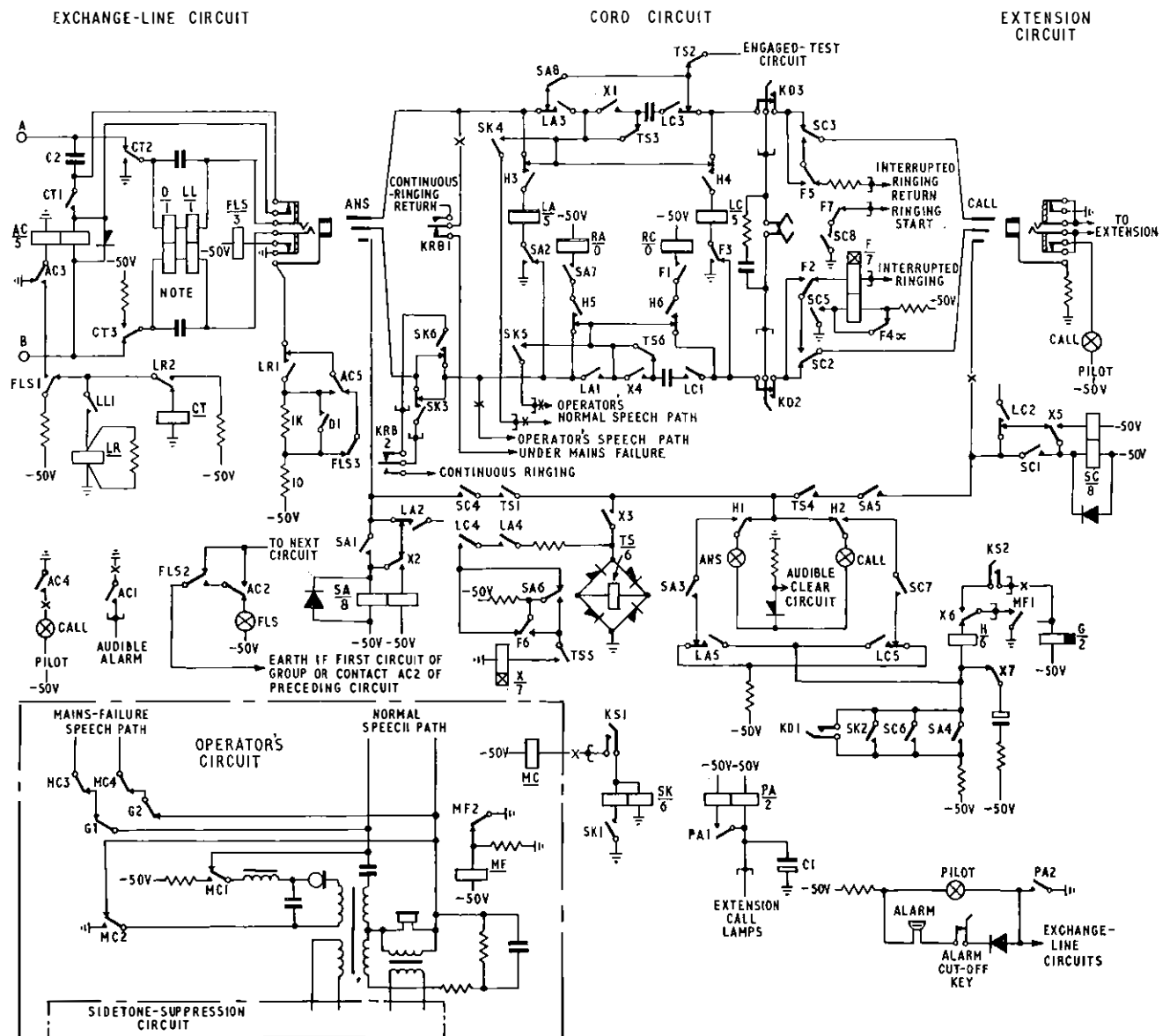
CIRCUIT DESIGN AND OPERATION

A simplified circuit diagram of the P.M.B.X. No. 4 is shown in Fig. 4. All extension circuits are 2-wire with earth-loop recall; for extension lines up to a 500-ohm loop resistance

the call lamp is lit directly from the telephone loop. Extensions up to a maximum loop resistance of 920 ohms can, however, be catered for by the introduction of a simple signalling unit; the telephone loop then operates a Type 12 relay, and the contact of this relay lights the call lamp. In practice, the permissible loop resistance may be governed by the exchange-to-extension limit.

Interconnexion of cord circuits, by the actuation of two keys to the SPEAK position, is prevented. The first key thrown operates relay SK in its own cord circuit. Relay SK, in operating, reduces the potential at the common point between the SK relays and the MC relay, thus preventing the operation of any other SK relay should another key then be operated to the SPEAK position. Interconnexion of two exchange lines via a single cord circuit is also prevented. With the answer plug in one exchange-line jack and the cord-circuit key thrown, relays H and LA operate and, if the call plug is inserted into another exchange-line jack, relay LC operates. Contacts LA4 and LC4 operate relay TS; contacts TS3 and TS6 split the cord circuit.

There is a specially-designed sidetone-suppression circuit in the operator's circuit. This new circuit has a dual function: to reduce the sidetone produced in the operator's receiver,



Note: Relay D is differentially connected

FIG. 4—Simplified circuit diagram of P.M.B.X. No. 4

and to limit loud received speech to an acceptable level on all types of call. Weak signals are not attenuated, and, for such signals, full advantage is taken of the increased efficiency of the receiver in the Headset No. 1.

The engaged-test circuit is a simple transistor switching circuit which operates to the negative potential present on the bush of an engaged jack to produce a click in the operator's receiver.

When free-line signalling (f.l.s.) is required, earth potential is connected to the f.l.s. contact chain in the first exchange-line circuit; subsequent circuits are strapped together to switch earth potential to the required f.l.s. lamp. The lamp is omitted from the first circuit of any group to save a permanent drain on the power supply.

Extension-to-Extension Call

When a call is originated at an extension, earth potential is connected via the jack-tip auxiliary springs, telephone loop and the jack-ring auxiliary springs to light the call lamp via the pilot relay, which operates. The pilot lamp lights and, if the ALARM CUT-OFF key is normal, the buzzer operates. Contact PA1 connects the low-resistance coil of relay PA in parallel with the higher-resistance operate-coil to prevent an excessive voltage drop being developed when several circuits are calling simultaneously. Capacitor C1 prevents overhearing between unanswered extensions. The call is answered by operating the cord-circuit key, KS, to the SPEAK position and inserting the answer plug into the appropriate extension jack. Operation of key contact KS1 operates relays MC and SK: contacts SK4 and SK5 connect the operator's circuit to the cord-circuit tip and ring, contact SK2 operates relay H to earth at contact MF1 (relay MF is normally operated), contacts MC1 and MC2 connect energizing current for the operator's transmitter. Insertion of the answer plug causes the jack auxiliary springs to disconnect the extension loop from the lamp and the pilot relay. The extension loop is then extended to the cord-circuit tip and ring, and relay SA operates to the extension sleeve earth. The operation of relays SA and H permits the operation of the supervisory relay LA via the extension loop to prevent the lighting of the cord-circuit answer supervisory lamp. The +50-volt potential and earth from the RA and LA coils, respectively, provide transmission power feed to the calling extension. On multiple installations the operator makes an engaged test on the required extension jack (see Engaged Test). On a single position, if the extension is free, the operator restores key KS to deal with other calls and inserts the cord-circuit calling plug into the required jack. On plugging-in, the called-extension call lamp is disconnected by the operation of the jack auxiliary springs and relay SC operates to the sleeve earth. Contact SC8 provides a "start" earth for the ringing converter, and contacts SC2 and SC3 apply the interrupted ringing (0.75 second on, 2.25 seconds off) to the required extension. Contact SC7 lights the call supervisory lamp. When the called extension answers, relay F operates and locks. Contacts F2 and F5 extend the extension A-wire and B-wire to the transmission feed provided via coil RC and by relay LC, which also operates. Contact LC5 dims the call supervisory lamp.

Either extension may recall the operator by depressing the telephone RECALL button. The earthed loop from the extension releases relay LA or relay LC, as appropriate, and contact LA5 or LC5 lights the required supervisory lamp.

On completion of the call, relays LA and LC release when the extension handsets are replaced, and the supervisory lamps are lit. Removal of the plugs releases relays SA, SC and H.

Extension-to-Exchange Call

If the calling extension requests connexion to an exchange line, the operator, having verified that a line is free, inserts the

calling plug into the exchange-line jack. The relays operated up to this stage are SA, LA and H and, if the operator remains in circuit, MC and SK. Insertion of the calling plug operates the jack auxiliary break springs; one pair releases relay FLS and the other disconnects the operate path of relay AC. Connexion of the sleeve circuit does not operate relay SC, as both the cord-circuit sleeve and exchange-line sleeve are connected to -50 volts. Contact FLS1 operates relay CT. Contact FLS2 steps on the f.l.s. earth on a multiple suite. Contact FLS3 applies -50 volts via a low resistance to the exchange-line sleeve circuit. Contacts CT2 and CT3 provide local central-battery conditions to operate relay LC, which is loop connected, and relay LL. Relay D is differentially connected and does not operate at this stage. Contact LL1 operates relay LR. Contact LR2 releases relay CT, and contacts CT2 and CT3 extend the cord-circuit tip and ring to the exchange line. Contact LR1 increases the resistance of the sleeve circuit to maintain the cord-circuit supervisory darkened. When relay LC in the cord circuit operates, contact LC4 operates relay TS to -50 volts via contact F6. Contact TS5 operates relay X to -50 volts via a resistor and contact SA6 operated. Contact X6 releases relay H and operates relay G, and contact X3 prepares a hold circuit for relay TS. Contacts H3, H4, H5 and H6 disconnect relay LA, retard coil RC, retard coil RA and relay LC, and complete the through-clearing path of the cord circuit. The extension loop is now extended to the exchange line and holds relay LL to the exchange -50 volts and earth. Relays LA and LC release. Relay TS is now held via contacts X3, TS4, SA5 and LR1 to -50 volts. The extension can now dial the required number. During dialling, relay LL operates and releases, but relay LR holds.

The extension may recall the switchboard during an established extension-to-exchange call. Operation of the RECALL button causes the earth loop from the extension telephone to operate the D relay in the exchange-line circuit. Contact D1 reduces the sleeve resistance to 10 ohms to light both cord-circuit supervisory during the depression of the button.

Incoming Exchange Call

Incoming ringing current operates relay AC on one coil via a capacitor and the jack auxiliary springs. Contact AC1 operates the audible alarm, contact AC2 steps forward the f.l.s. earth, contact AC3 locks relay AC and contact AC4 lights the call lamp. The operator answers the call by operating the cord-circuit key to the SPEAK position and inserting the answering plug in the exchange-line jack. Insertion of the plug releases relay FLS and disconnects the operate path of relay AC. Relays SK and H operate in the cord circuit to connect relay LA across the tip and ring conductors. Contact FLS1, released, operates relay CT and releases relay AC. Contact FLS2 maintains the f.l.s. switching. Contact FLS3 connects -50 volts via a resistance to the exchange-line sleeve. Contacts CT2 and CT3 extend -50 volts and earth to the cord-circuit tip and ring to operate relays LL and LA. Contact LL1 operates relay LR, and contact LR1 connects -50 volts via a high resistance to the sleeve to keep the cord-circuit supervisory lamps dimmed. Contact LR2 releases relay CT. Contacts CT2 and CT3 extend the cord-circuit tip and ring to the exchange line, and relay LA trips the incoming ringing current (if the call is from an automatic exchange) and operates to the exchange -50 volts and earth. The exchange call can now be extended to an extension if required. The circuit functions as previously described, i.e. the extension is rung, the ringing is tripped and relay LC operates as for an extension-to-extension call. On the operation of relay LC, contact LC4 operates relay TS, and the circuit functions as for an extension-to-exchange call, except that relay TS is held via contacts TS1 and SC4 to the exchange-line jack sleeve connexion. If the operator has to leave the circuit and

the call is not extended to an extension the automatic hold condition is applied.

Automatic Holding of Exchange Calls

When an exchange call is answered (or originated) by the operator and the cord-circuit key has been actuated, relay H is operated (via key contact SK2) and relay LA (or LC) operates to the line conditions and applies a holding loop. Contact LA5 (or LC5) holds relay H via contact X6 to contact MF1 if the key is restored. This automatic hold condition is maintained until either the plug is removed or the call is extended to an extension; the cord circuit then provides through-clearing (relay H is released by contact X6, operated).

Follow-on-Call Trap

If, on an exchange-to-extension call, the extension clears but the operator does not remove the plugs, the bell on the extension is not rung should another incoming call be received on the exchange line.

When the extension clears, relay LL releases and contact LL1 releases relay LR. Contact LR2 released re-operates relay CT. Contact CT1 reconnects relay AC across the exchange line and contacts CT2 and CT3 disconnect the exchange line from the cord circuit. An incoming call received on the exchange line operates relay AC, but relay AC does not lock because relay FLS is released. Contact AC5 applies -50 volts via high and low resistances alternately to the exchange-line jack sleeve to flash both cord-circuit supervisory lamps.

Audible Clear

If provided, the audible-clear circuit is only operative when a double clear is obtained on a cord circuit. Under this condition the potential across a resistor in the cord circuit due to both lamp currents is approximately 7.2 volts. This potential, when applied to the base of transistor VT1 (Fig. 5),

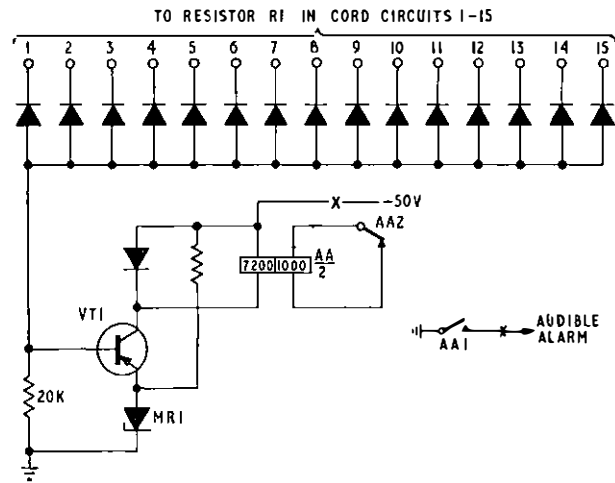


FIG. 5—Audible-clear circuit element

switches on the transistor and the emitter-collector current produced operates relay AA. Contact AA1 applies earth to the audible alarm. Relay AA is made slow to operate via contact AA2 to prevent the operation of relay AA during the warm-up time of one lamp, i.e. when the lamp is low resistance and taking sufficient current to produce a voltage sufficient to switch on the transistor. Zener diode MR1 ensures correct switching with lamps of different manufacture.

Reverted Call

A reverted call is one completed when the operator has an established exchange connexion on the calling cord and requires to ring an extension on the answer cord. The outgoing call is set up as previously described for an extension-to-

exchange call except that relays LA and SA are not operated, and, therefore, relays X and TS are not operated and relay H does not release. The answer plug is inserted into the required extension jack, and the cord-circuit key and common RING ANSWER key actuated. Continuous ringing is applied to the answer-cord tip and ring via contacts KRB1 and KRB2 and SK3. When the called extension answers, relay LA operates to the extension loop and the cord circuit gives through clearing when contact LA4 operates relay TS.

Engaged Test

The engaging potential on the bush of a busy circuit may be between -13 volts and -50 volts, depending on circuit conditions. An engaged test is made in the usual manner, with the cord-circuit key operated to the SPEAK position, by tapping the tip of the calling (or answering) plug on the bush of the required circuit. The bush potential is passed via contacts SC3, KD3, LC3 and TS2 to the engaged-test circuit (Fig. 6). For the answer plug the circuit is via contacts LA3,

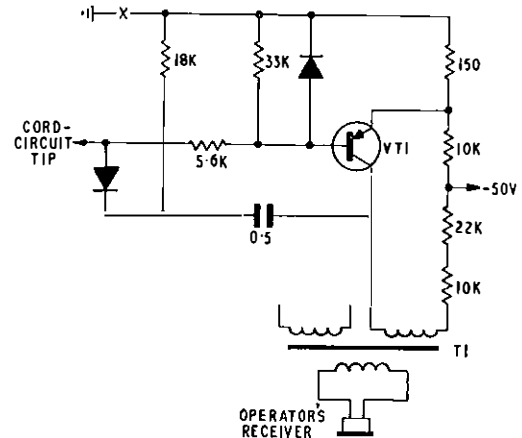


FIG. 6—Engaged-test circuit element

SA8 and TS2. The busying potential applied to the base of the transistor VT1 causes the transistor to switch on and a pulse of current to flow in the emitter-collector circuit. The pulse of current through the winding of transformer T1 causes the click in the receiver.

Metering

Centralized extension, cord-circuit trip and exchange-line totals metering may be provided independently or in any combination. Fig. 7 shows the circuit arrangement for the three facilities.

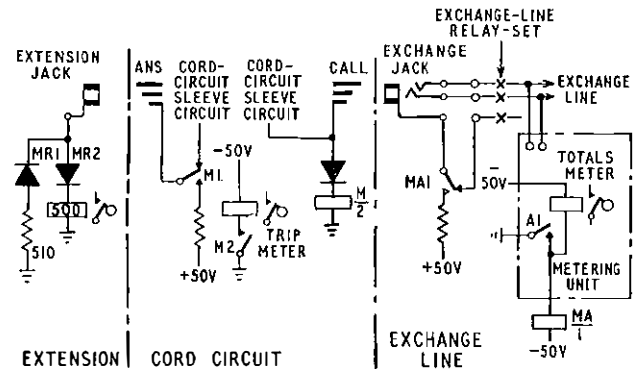


FIG. 7—S.T.D. metering circuit element

A metering unit is associated with the exchange line on the line side of the exchange-line relay-set. Subscriber-trunk-dialling meter pulses received in the metering unit cause the operation of relay A. If totals metering is required, contact A1 steps the totals meter only. If cord-circuit or extension

metering is required, relay MA is provided in association with the exchange-line metering unit, and relay M is provided in the cord circuit. Relay MA operates when pulses are received and contact MA1 connects a positive potential to the sleeve circuits to operate relay M in the cord circuit. If cord-circuit trip metering is required the trip meter is provided; it is operated by contact M2. If centralized extension metering is required a Meter No. 150A and diodes MR1 and MR2 are provided on the extension sleeve circuit; the meter operates to a positive potential connected to the sleeve circuits by contact M1.

Relays M and MA and associated resistors and diodes are provided in units mounted external to the switchboard. The positive supply is obtained from a separate mains-operated power unit or rectifier-and-battery arrangement, as required.

Mains Failure

The circuit design has been arranged so that, at installations supplied from a mains-operated power-unit, exchange-line service is maintained in the event of a mains failure.

On an established exchange-to-extension call the speech path through the cord circuit is via unoperated relay contacts, and the release of relays SA, SC, X and TS does not affect the call. If the power is restored during a call the circuit is set up again as for a normal call. Extension-to-extension calls will fail, as all relays are released and the transmission power feeds are lost.

Selected extensions can be given direct exchange access during mains failure by suitable connexion of cords. Under this arrangement the call cord is connected to the exchange line to prevent the extension telephone being rung on restoration of the power. The operator may originate calls on any cord-circuit call cord if the answer cord is connected to a hold jack, as, during mains failure, the operator's circuit is a common-battery type circuit via contacts MCI and MC2. Operator-originated calls cannot be connected to an extension.

Incoming calls are indicated by a non-locked signal on the exchange-line lamps, the reserve —50-volt battery being used to light the lamp. An incoming call operates relay AC, and contact AC4 lights the call lamp for the period of ringing current. On plugging-in, the operator disconnects the operate circuit of relay AC and the ringing is tripped by the telephone loop. The hold jacks may be utilized to hold the call if the operator needs to answer a further call.

Night Service

Operation of the NIGHT SERVICE key disconnects the —50-volt supply from the switchboard, one key being provided per position. Night service is set up in a similar manner to the mains-failure arrangement for connecting selected extensions to exchange lines.

Inter-PBX Extensions and Private Circuits

The type of jack used for inter-P.B.X. extensions and private circuits has one auxiliary make-contact unit in addition to the normal tip, ring and sleeve contacts. Use is made of this auxiliary contact unit to set up relays in the signalling units associated with these circuits. The signalling units are mounted external to the switchboard.

CONCLUSION

The versatility, better appearance, additional facilities and improved circuit design of the P.M.B.X. No. 4 should prove attractive to subscribers, and provide greater reliability and ease of maintenance for the Post Office.

ACKNOWLEDGEMENT

The authors wish to thank the Plessey Telecommunication Group, who, as the liaison manufacturers, worked in close co-operation with the British Post Office on the development of the new P.M.B.X.

Book Review

“Radio Communication.” J. H. Reyner, B.Sc., A.C.G.I., D.I.C., M.I.E.E. and S. P. Reyner, M.A.(Cantab), A.M.I.E.E. Sir Isaac Pitman and Sons, Ltd. xiv + 777 pp. 510 ill. 60s. (cloth) 45s. (paper).

This book has made great strides since the first appearance of its forerunner “Modern Radio Communication” in 1924. It has been quite popular with students since those early days, and it is probable that the present volume will achieve the same measure of success. It was first published in its present form in 1962 and this Second Edition now comprises 777 pages. As in the previous edition there are two main sections, devoted to basic principles and practical applications, and a further section of 63 pages includes typical questions taken from City and Guilds and I.E.E. examination papers. The declared aim is principally to cover the City and Guilds Telecommunication Technicians' Course in radio subjects.

The book begins with an introduction to fundamental concepts that the absolute beginner would wish to know. Then follows a chapter dealing with circuit theory including vector and j notation, bridge networks and inductive circuits. The principles of radio communication are considered in the next chapter but the theory underlying radiation and field-strength is rather too briefly dismissed. The chapter on practical components contains a useful section on trans-

formers. The chapter on thermionic valves is largely unchanged, but that on semiconductors has been greatly expanded and now constitutes a comprehensive introduction to transistor operation and circuit analysis.

The second part illustrates the way in which the basic ideas considered earlier may be employed in practice. These chapters include transmitters, receivers, aeriels and power supplies, and in additional chapters, filters and attenuators and aspects of measurement and pulse techniques are considered. As a charming testimony to the book's ancient heritage, the section dealing with h.f., v.h.f. and microwave practice is named “Short-Wave Technique.”

Coverage of a very wide field has been attempted and consequently the treatment of certain aspects is somewhat sketchy. This is of course inevitable if the book is to be kept to reasonable proportions, but perhaps, for instance, the section on generators and motors could have been more usefully replaced by further information on television—the treatment of which is very brief. Errors are thought to be few, but a surprising one occurs in two separate figures where the frame scan of a television picture is shown in the direction bottom to top.

The book should prove useful to the average student.

P. J. L.

Development of Bow and Stern Whiskers for Cable Ships

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When laying Lightweight submarine telephone cable, consideration has to be given to the radius of curvature of all surfaces over which the cable may pass, because such a cable is more susceptible to damage by severe bending than conventional armoured cable. The design of the cable-guiding platework (whiskers) associated with the overboarding sheave of a cable ship is described. H.M.T.S. Monarch is fitted with bow and stern whiskers to the new design; H.M.T.S. Alert has only been fitted with stern whiskers at present.

INTRODUCTION

This article describes the development of the shaped fairings (known as whiskers) which are associated with the outboard sheaves of cable ships.

It is well known that cables, when being laid or recovered by a cable ship, pass over a sheave situated either in the bows or stern of the vessel, and, since it is often impossible for the ship to be lying in the same direction as that of the cable, shaped fairings have long been used around the sheave to control the movement of the cable as it leaves the sheave and passes down the side of the ship into the water. Whiskers are of considerable importance in the control of the cable; in the past they have been of somewhat limited size and, consequently, cable passing over the surface of them may under some circumstances have experienced fairly small radius bends before entering the water (Fig. 1). With the

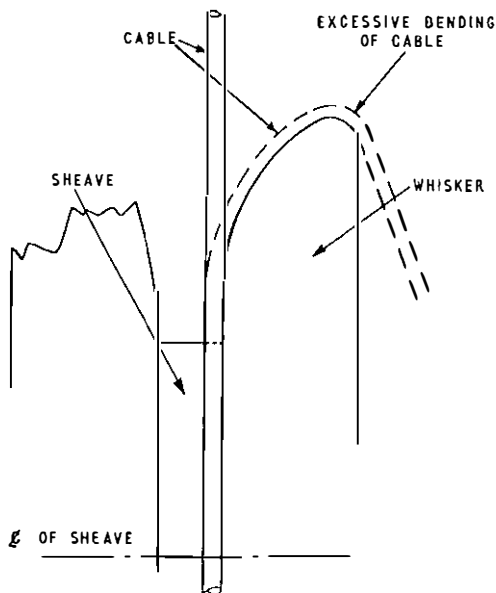


FIG. 1—Plan view of whiskers to old design

older types of cable (especially externally-armoured cables) this situation has been reasonably acceptable, but the emergence of the much more economical Lightweight cable* has

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* BROCKBANK, R. A., CLARKE, E. F. S., and JONES, F. Anglo-Canadian Transatlantic Telephone Cable (CANTAT): Cable Development, Design and Manufacture. *P.O.E.E.J.*, Vol. 56, p. 82, July 1963.

reacted upon the design of the whiskers. Lightweight cable is capable of only a limited number of bends, and these should not be of a smaller radius than 3 ft. Consequently, it was necessary to redesign the shapes of the whiskers in order to avoid subjecting the cable to more severe bends than this.

The single stern sheave is used for laying operations only; in this work the cable generally leaves the ship at a fairly small angle of depression from the horizontal, and only during the time of laying a repeater will it approach an almost vertical descent to the water. On the other hand, repair and recovery work is carried out over the bow sheaves, three of which are provided on the larger ships. Under these circumstances the requirements of navigation may cause the cable to leave the ship in almost any direction: in particular, when a repair is being carried out, two cables will be held at the bows and, of necessity, these will be leading away from the ship in different directions. When Lightweight cable is being handled it is preferable to use a flat-surfaced sheave for the cable to run over, but externally-armoured cable and grapnel rope are better handled on a sheave with a V-shaped surface.

FUNCTION OF WHISKERS

It is useful to consider in detail the functions which whiskers have to perform. Firstly, they guard against the cable slipping off a sheave, and restore it to its original position on the sheave if for any reason it jumps momentarily upwards. Secondly, together with the sheave, the whiskers change the direction of travel of the cable from that which it follows on board to the line it assumes when passing outboard. In some circumstances this change of direction is in the vertical plane only; in others it has both vertical and horizontal components, and then the corresponding whisker has to provide support and guidance for the cable along its curved path. Finally, the whiskers must be so shaped as to ensure that the change of direction of the cable takes place smoothly, and that at every instant the cable is in a stable condition and has no tendency to slip suddenly across the surface of the whisker.

In designing whiskers, attention has to be given to the visibility of the area around and under the whiskers where the cable emerges from the water, and to the accessibility to this cable so that preparation work can be carried out, e.g. "stoppering-off"‡ a suspended cable, which is done by a man lowered over the side in a bosun's chair. Furthermore, the whisker structure must not endanger the seaworthiness of the ship, and must not unduly limit the performance of the ship when steaming or working in rough seas.

‡ Stoppering-off a cable involves securing a handling rope to the outside of the cable.

DETERMINATION OF THE GEOMETRICAL SHAPE OF WHISKERS

In analysing the geometrical shapes which could be adopted in the construction of whiskers, first consider the whiskers associated with a single sheave and only the basic requirement which forbids bending of the cable over a curved surface of less than 3 ft radius. A simple construction of such a whisker is an assembly of two 3-ft-radius cylinders, one positioned at right angles with respect to the other, and married together with a sphere, as shown in Fig. 2. This

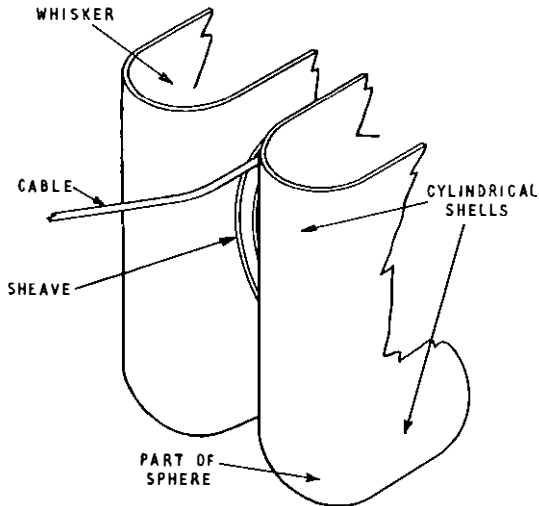


FIG. 2—Whiskers composed of simple three-dimensional shells

shape is also very attractive from the manufacturing point of view as bending $\frac{1}{2}$ in. steel plate (of which such whiskers are made) should be limited to the most simple shapes. This construction of the whiskers can, however, be modified and reduced in size without reducing the bending radius of the cable to an unacceptable value.

Analysing the problem mathematically, it can be assumed that cable, when passing over the whisker, is under a tension sufficiently high to enable all gravitational, frictional and

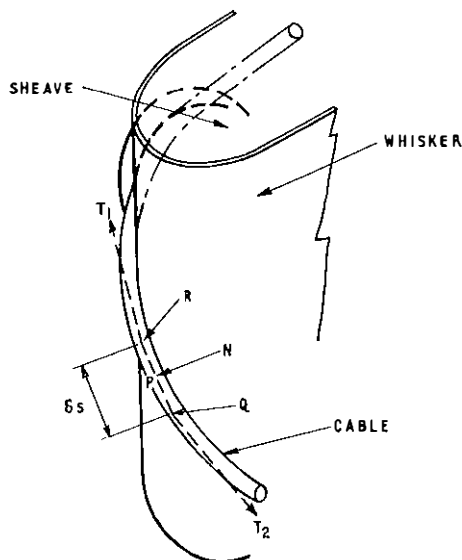


FIG. 3—Cable in equilibrium on the surface of a whisker

torsional forces to be neglected. The longitudinal motion of the cable does not affect this analysis, as the dynamic and frictional forces produced may also be neglected. Hence, the path of the cable on any element of the whisker may be assumed to be a geodesic, which is defined as a curve on a surface such that its osculating plane* at any point contains the normal to the surface.

To prove that the path of cable on the whisker is a geodesic take a small segment of cable, QPR, passing over the whisker surface (see Fig. 3). The only forces acting on this segment are the tensions T_1 and T_2 , and the reaction of the surface. When Q and R tend to P ($\delta s \rightarrow 0$) and the lines of action of the tensions approach the osculating plane of the cable at P , the reaction of the surface approaches the normal reaction N at P . For equilibrium between these forces, the osculating plane of the cable at P must contain the normal to the surface at this point, and, thus, the cable at P is a geodesic. This condition is satisfied along the whole path of the cable across the whisker.

A geodesic on a cylinder is a circular helix which cuts all generators at a constant angle θ . The curvature $1/\rho$ of this helix is given by the following equation:

$$\frac{1}{\rho} = \frac{1}{r} \sin^2 \theta,$$

where ρ = the radius of bending of the cable, and r = the radius of the cylinder.

On a sphere a geodesic is always a great circle, from which it follows that the stable condition for a cable under tension and in contact with a spherical surface occurs only when the plane containing the cable passes through the centre of the sphere; under these conditions its radius of bending cannot be greater than the radius of the sphere.

Stern Whiskers

In designing stern whiskers for H.M.T.S. *Monarch* and H.M.T.S. *Alert*, it was assumed that the angle contained between the cable and horizontal plane, further referred to as the laying angle α , is small and, in practice, never exceeds 60° . This implies that under normal laying conditions the effective part of the whisker where the cable meets its surface is only the vertical cylinder. The justification for this assumption lies in the fact that stern laying is only practicable while the ship has steeerage way on her. Vertical cable angles require more freedom of manoeuvre than can be obtained with a cable over the stern.

For laying angle $\alpha = 0^\circ$ the cable crosses the generators of the vertical cylinder at $\theta = 90^\circ$, and thus

$$\frac{1}{\rho} = \frac{1}{r} \sin^2 90^\circ, \text{ or } \rho = r,$$

i.e. the bending radius of the cable is equal to the radius of the cylinder.

Similarly, for a laying angle of $\alpha = 60^\circ$,

$$\theta = 30^\circ \text{ and } \rho = 4r.$$

This shows that, without decreasing the radius of bending of the cable below the specified 3 ft, the vertical cylinder can be replaced by the frustum of a cone, the top cross-section of which is of 3 ft radius. The smaller radius of the frustum could be considerably reduced, but this is limited by the need to maintain acceptable radii on the sphere and lower cylinder—a 2 ft radius was used as a compromise value for this radius on H.M.T.S. *Monarch* and a 2 ft 3 in. radius was used on H.M.T.S. *Alert*.

The actual design was performed by making 1-to-12 scale models of the stern of each ship. The models were used for attaining the best shape to ensure stability of the cable and ease of manufacture. They also were used for passing the information from the designer to the shipyard responsible for preparing working drawings and for the construction and installation of the whiskers. Fig. 4 shows the stern whiskers fitted to H.M.T.S. *Monarch*.

* The osculating plane of a curve—if Q , P and R are points of a curve, and Q and R tend to P , the limiting position of the plane PQR is the osculating plane at the point P .

The sea trials of the modified stern whiskers and a number of laying operations proved their considerable advantages over the old design. It was also apparent that with the new whiskers the ship could be manoeuvred much more freely while laying cable, and this, in turn, should lead to economies in the length of cable laid in difficult operations. The same freedom of manoeuvre also makes it possible to avoid damage to a cable when the conditions of weather compel the safety of the ship to override that of the cable.

Bow Whiskers

The design of bow whiskers is considerably more complex than that of the stern whiskers because of the requirements imposed by the functions they have to perform. At the bows it is preferable to have two flat sheaves, for handling Lightweight cable, and one V-sheave, for armoured cable and grapnel rope. In picking up operations, the V-sheave is required for handling armoured cable as, by manoeuvring the ship so that there is the correct side lead on the cable, it is possible to make the cable roll down the face of the V-groove of the sheave so ensuring easy coiling of the cable.

The two flat sheaves are used for handling Lightweight cable on the port and starboard sides of the ship. Two are essential when repair operations are in progress, as, with the help of the two cable engines, the two legs of a bight can then be handled independently.

The angle contained between the cable and horizontal plane is no longer limited to 60° as at the stern, and an assumption must be made that cable can meet the whiskers from any direction; furthermore, the reduction of the radius of bending of the cable to 2 ft at the lower parts of the whiskers cannot be tolerated. At the same time, the width of structure, measured across the whiskers, is increased by the presence of the three sheaves. This width increase must be

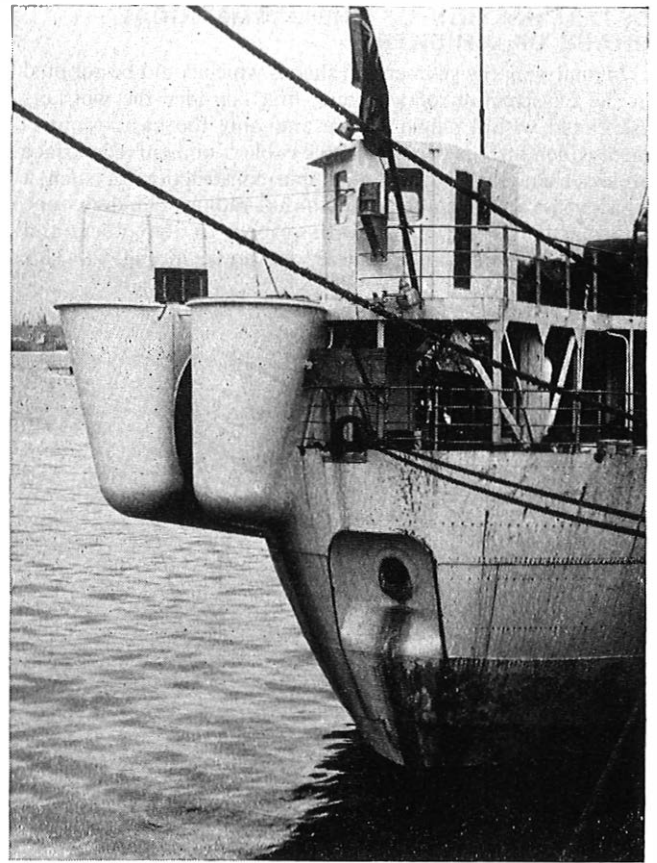


FIG. 4—Stern whiskers of H.M.T.S. *Monarch*

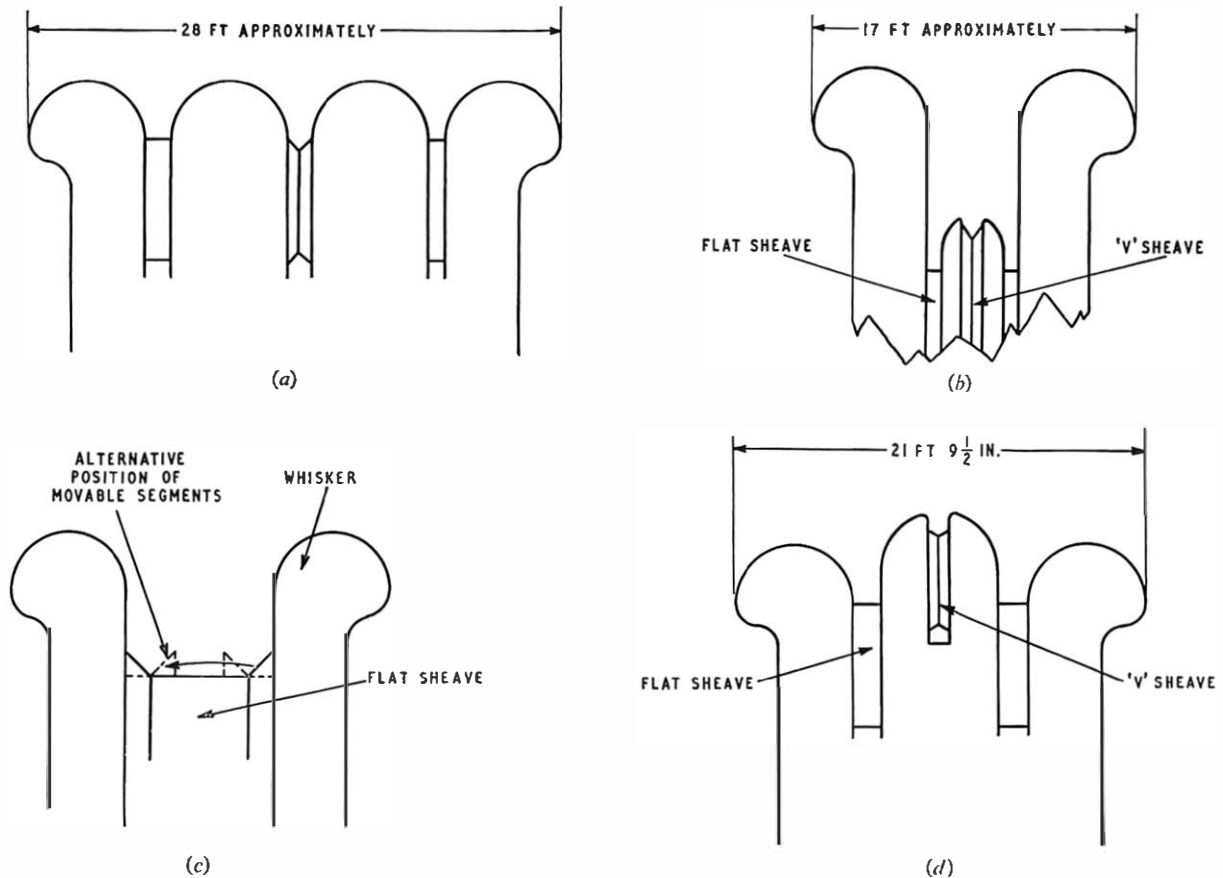


FIG. 5—Possible variations of sheaves and whiskers

kept to a minimum as it can interfere with the performance of the ship and may considerably reduce the maximum safe speed in rough weather conditions.

The arrangement of the sheaves in the horizontal plane was studied carefully, and Fig. 5 shows several variations which were considered possible.

It was realized from the beginning that it is practically impossible to provide 3 ft-radius whiskers for each sheave (see Fig. 5(a)); as the total width of such a whisker structure would be approximately 28 ft, some compromise had to be reached. Once it was established that only the two flat sheaves (7 ft diameter and 15 in. wide) would be used for handling Lightweight cable and repeaters, then it was necessary only for the whiskers associated with flat sheaves to be designed to ensure that the 3 ft bending radius was preserved. The V-sheave will be used mainly for grapnel rope and for picking up heavy armoured cables which are unlikely to be damaged by excessive bending; and, thus, the whiskers of this sheave can be similar to the old design. This restriction of use also permitted the diameter of the V-sheave to be reduced to 4 ft 6 in. and, with the sheave width held at 9½ in., the overall width of the whisker structure was considerably reduced. Fig. 5(b), (c) and (d) show the remaining three possible arrangements of the sheaves. The construction of Fig. 5(b) is of great advantage as the total width of whiskers is only 17 ft, and it preserves the simple assembly of three independent sheaves. However, this construction had to be rejected as it introduces difficulties in grappling for shallow-water cable. When lifted from the sea bed, this type of cable is usually bar-tight, and the two side whiskers extending forward of the grapnel sheave would not allow the cable bight to be lifted to the deck level; the cable would, therefore, have to be stoppered below the whiskers, a very difficult and dangerous operation in rough weather. Thus, this construction had to be rejected in spite of its apparent advantages.

Fig. 5(c) has also the great advantage of a small width. It is basically a one-sheave construction, and thus has only two whiskers; its sheave, however, is a composite one, consisting of a flat sheave to which V-segments could be secured when required to convert it to a V-sheave. The same conversion could also be achieved by having more than one sheave on the same spindle and arranging the spindle to be traversed to expose the desired sheave, but this apparently simple solution poses difficult practical problems when the magnitude of the load on the sheaves is considered.

Careful analysis showed that the best system of sheaves would be the one shown in Fig. 5(d). The sheaves are mounted on independent bearings to ensure simple and

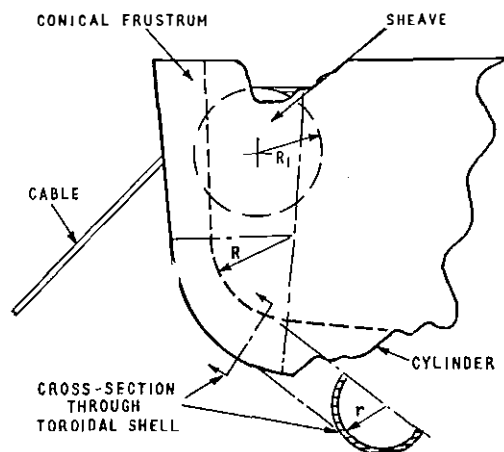


FIG. 6.—Composition of principal elements to form a bow whisker

reliable operation, while the V-sheave is forward of the whisker construction where it is in the best position for cable-repair operations. The overall width of under 22 ft was reduced at lower cross-sections by shaping the sides so as to reduce shock when the bow of the ship plunges into high waves.

The bow whiskers were modelled on the original construction adopted at the stern, but with one considerable deviation. The vertical cone and horizontal lower cylinder were married together with a torus instead of a sphere, which, apart from some difficulties encountered in manufacture, has two main advantages over the sphere. The whole assembly provides better support for the cable as it passes from one position into any other, and, as opposed to the sphere in the stern whiskers, has no unstable areas. For the same width of the whiskers the actual radius ρ of bending (see Fig. 6) of the cable over a toroidal surface is greater than over the sphere. This radius is a function of the two radii (r and R) of the torus and the radius R_1 of the sheave, and can be calculated from the following equation:

$$\frac{1}{\rho} = \frac{1}{r} \left[1 - \frac{R_1^2 R}{(R + r)^3} \right];$$

it can also be taken from the graph shown in Fig. 7.

The actual shape of the whiskers was arrived at by working on a model and adapting the aforementioned geometrical shapes, namely, cone, torus and cylinder, to fit the construction of the ship and other requirements such as naval-construction characteristics, visibility, accessibility for work on the outboard cable, etc.

The initial installation of this whisker system was on H.M.T.S. *Monarch*, and Fig. 8 shows the final stage of the model made at the Post Office Research Station and used by the Vickers, Ltd., Shipbuilding Group at Hebburn-on-Tyne for making working drawings and for the

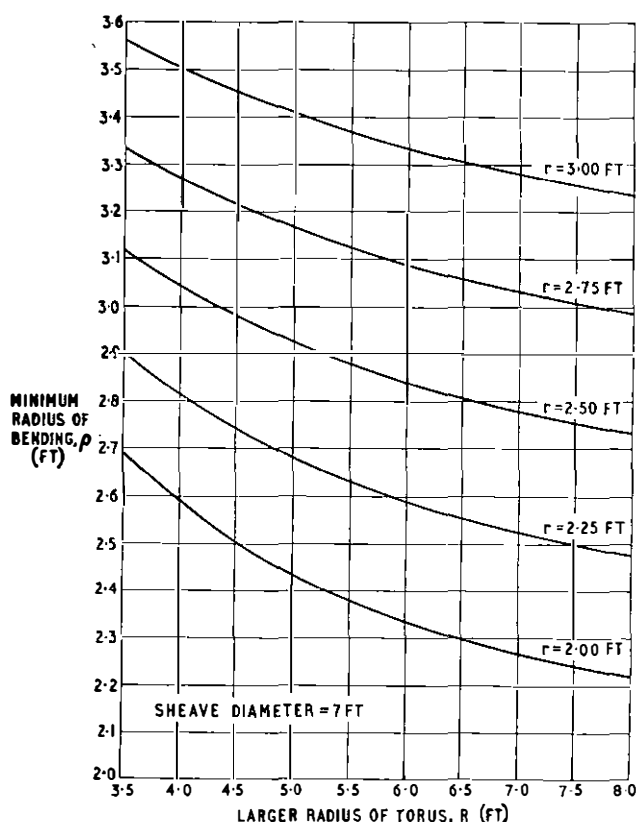


FIG. 7.—Values of the minimum radius of bending of a cable passing over a toroidal surface

construction and installation of the actual whiskers. Fig. 9 shows the bow whiskers fitted to H.M.T.S. *Monarch*.

Lifting facilities over the sheaves have been provided by a rigid gantry consisting of two overhead beams extending from the middle deck area to the bows. A monorail travelling hoist, of 2 tons capacity and 20 ft span, covers the whole cable-working area on the fore deck. On the top of the overhead beams, provision has been made for an observation platform, equipped with engine-room telegraph, compass repeater, etc., which can be positioned at the forward end of the beams during cable working and used by the officer in control of the work. The platform and hoist can be brought back for housing inboard and, thus, are less exposed to weather except when on cable work.

CONCLUSIONS

As indicated in the foregoing article, H.M.T.S. *Monarch* and H.M.T.S. *Alert* have, for some time, been fitted with new stern whiskers, and, in April 1966, *Monarch* was fitted with the new-type bow whiskers.

In practice, the installations have been found to fulfil adequately the design expectations, and have worked well. It is expected that the design of bow whiskers for future cable ships will follow the principles described.

ACKNOWLEDGMENTS

The authors wish to express their thanks to Mr. T. B. M. Neill for his mathematical analysis of the cable bending problems, and to Mr. C. J. Clarke for his design work in the earlier stages of this project and for his subsequent work, in conjunction with Submarine Branch, Network Planning and Programming Department, in supervising the installation of the whiskers and associated equipment on H.M.T.S. *Monarch* and H.M.T.S. *Alert*.



FIG. 8—Model of H.M.T.S. *Monarch*'s forward deck and bow whiskers

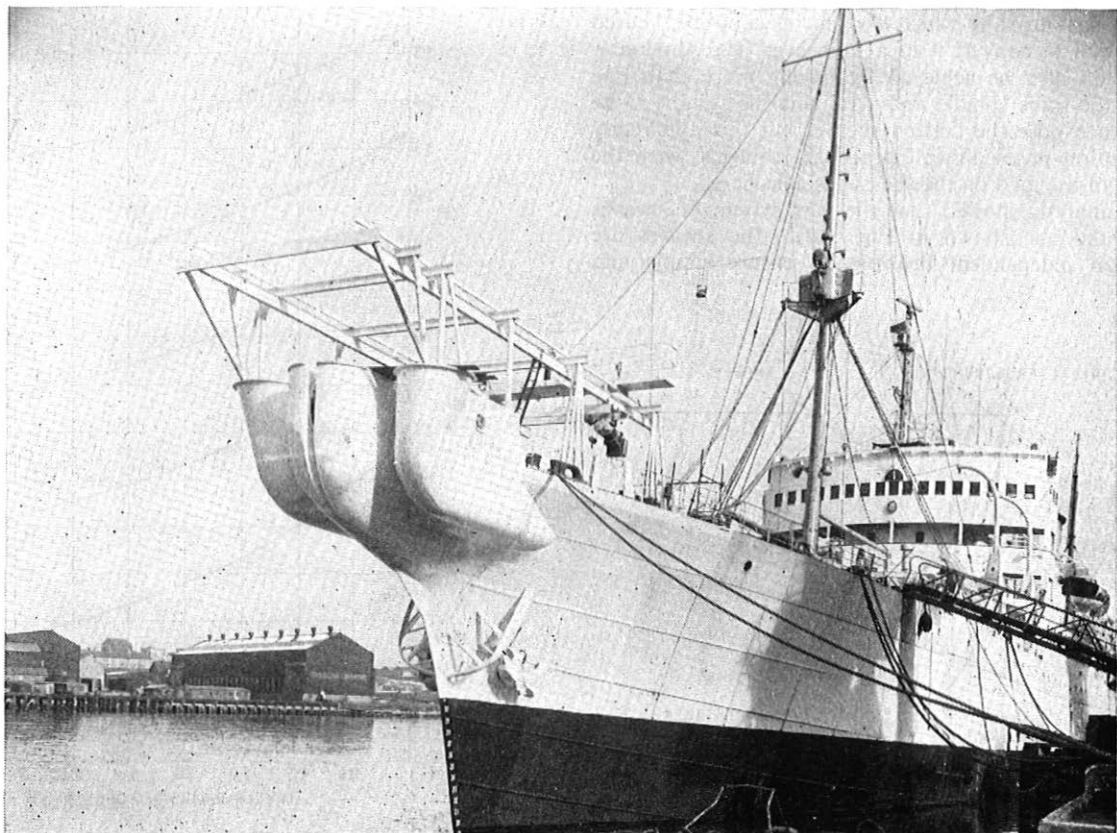


FIG. 9—Bow whiskers of H.M.T.S. *Monarch*

Design Features and Application of the British Post Office 24-Channel Pulse-Code-Modulation System

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The development of pulse-code-modulation systems has been progressing during the past few years and has now reached the stage where 24-channel systems are being installed to provide additional junction circuits. This article outlines the basic principles and advantages of pulse-code modulation, and discusses some of the factors which influenced the choice of parameters for the British Post Office design.

INTRODUCTION

The continuing increase in demand for trunk and junction circuits has stimulated the search for new means to provide additional circuits, rapidly and at low cost. The practical realization of pulse-code-modulation (p.c.m.) systems provides this means and makes possible morc circuits on existing junction cables.

For circuits longer than 20 miles it is generally economic to provide multi-channel systems using frequency-division multiplex (f.d.m.). The systems in use are 24-channel carrier

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employing separate pair-type cables for go and return directions, coaxial systems on 0.375 in. tubes providing bandwidths up to 4 MHz, and a limited number with a bandwidth of 12 MHz. These, together with a network of microwavc radio-relay systems in the 2, 4, 6 and upper 6 GHz bands, form the bulk of the trunk network.

The network, however, requires a measure of balance between provision by cable and radio, and the next few years will see the introduction of modern 12 MHz transistor systems into the coaxial-cable network.

In the "short-haul," i.e. less than 20 miles, little development has taken place in this country except for the provision of a carrier system for use on deloaded audio cables which

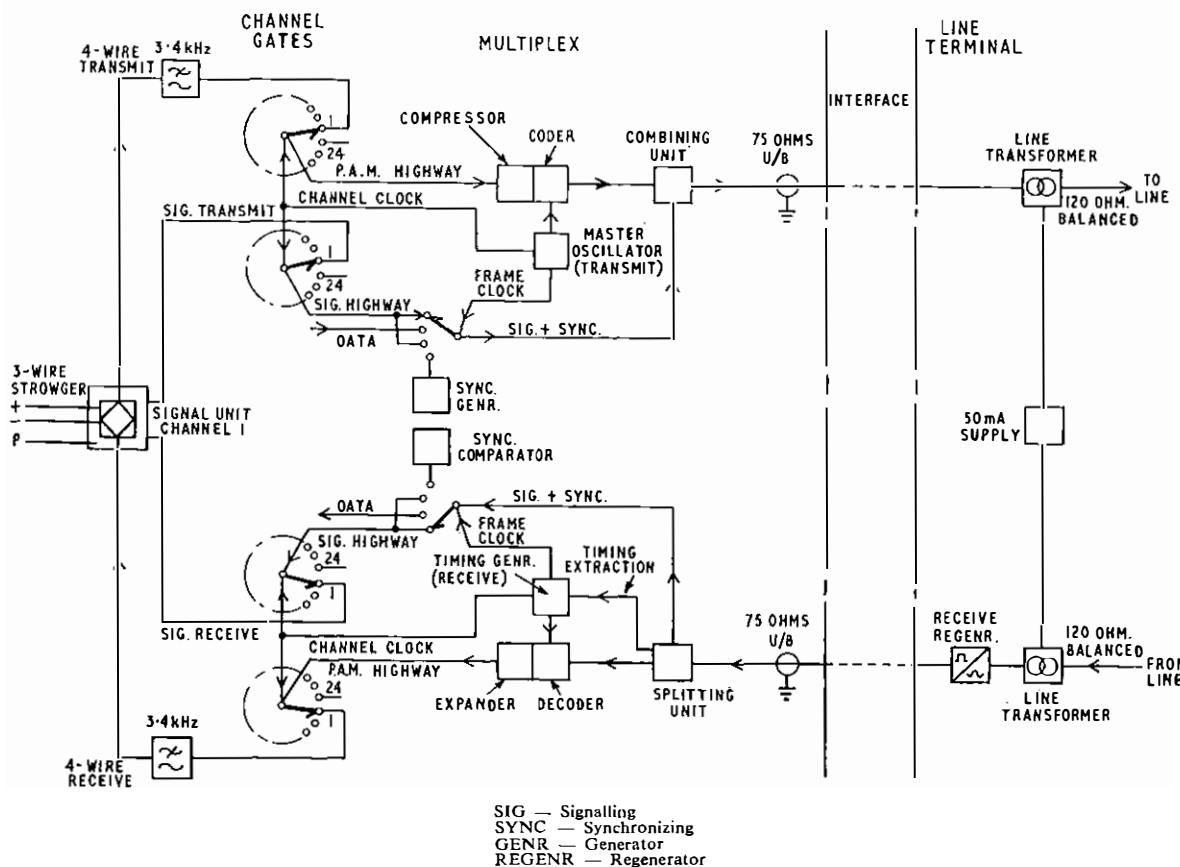


FIG. 1—Typical block schematic diagram of p.c.m. multiplex and line terminal

has a limited application since only one system in each balancing group of a cable is possible and it is relatively expensive. Trials of f.d.m. short-haul systems have taken place; these have not proved to be economic and little further interest has been shown in this country, although such systems are used extensively in North America. Present commitments for growth on junction routes are to some extent being met by the conversion of 4-wire amplified circuits to 2-wire, thus doubling the capacity of existing cables, but, once this process has exhausted the capacity of a route, it is necessary to consider the next step.

Often a spare bore in a duct way for additional cables is not available and the high cost of civil engineering works—and, even more important in the centres of major cities, the difficulty of providing further duct ways—makes it attractive to consider other methods of increasing the traffic-carrying capacity of existing cables.

Pulse-code modulation was patented in France in 1938 as a result of work by A. H. Reeves. The techniques evolved were incapable of realization economically until the availability of suitable components, particularly semiconductor devices. Several companies showed an interest in this approach to the problem of providing multi-channel systems on cables designed for use in the audio-frequency range, and as a result the British Post Office conducted field trials of three systems, which were installed on the Guildford–Haslemere, Reading–Marlow and Coventry–Rugby routes.¹ Current plans are for the installation of 920 systems catering for normal traffic by December 1969.²

PRINCIPLES AND TRANSMIT MULTIPLEX

An article in an earlier issue of this Journal discussed the fundamental theory of p.c.m.³ The present article gives a broad appreciation of the principles involved and describes the type of system used in the junction network.

Fig. 1 shows a typical block schematic diagram of a terminal, with the 2-wire of the junction connected to a hybrid transformer associated with a "signalling unit."

Each speech channel is connected, via a low-pass filter to limit the frequency range of the audio signal, to the channel-sampling gate. The sampling gates are timed from an 8 kHz clock source which opens each gate once every 125 μ s, so that for a 24-channel system a time of 125/24, i.e. 5.2 μ s, is available for each channel. To avoid interaction between adjacent timing slots it is advantageous not to use the whole width of the pulse slot. The sampling rate of 8,000 times per second is chosen for two reasons. The first is that the pulse-amplitude-modulated (p.a.m.) signal, which is obtained by the sampling process, will contain the upper and lower sidebands of the sampling frequency (and of its harmonics) together with the sideband of zero frequency (d.c.), as shown in Fig. 2. If other sidebands overlap into this sideband then retrieval will be impossible, so that the sampling rate must, for the general audio case, be at least twice the highest frequency it is required to transmit. The second consideration is that harmon-

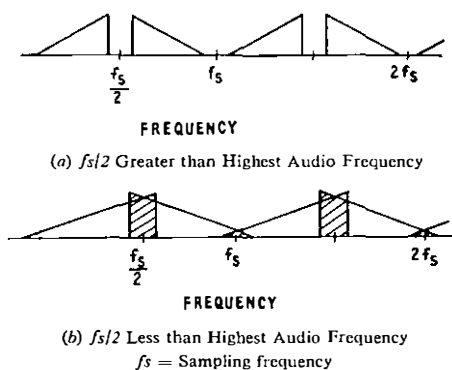


FIG. 2—Sidebands of sampling frequency

ics of the sampling rate, which may appear in the audio outputs, should fall in the inter-channel spaces of f.d.m. channel-ends that may exist in the same cable.

The successive p.a.m. pulses from the channel gates are connected in time sequence on to a common path or "highway," and it is then necessary to convert these amplitude pulses, which are analogue in form, into a binary code which is in digital form.

The heart of this process is the encoder which examines each of the pulse magnitudes in turn as it is presented to it from the p.a.m. highway, compares the sample with a number of standard magnitudes, or quantizing steps, and approximates the sample to the nearest quantizing step. It then ascribes a binary code to this sample, which is the essential information describing the magnitude of the particular sample examined.

The encoder requires 128 quantizing steps between a peak positive and a peak negative analogue signal, and to represent these steps as binary numbers requires 7 digits (i.e. $2^7 = 128$). The encoder uses 6 digits to describe the amplitude of the analogue signal and precedes these with a "sign" digit which indicates whether the analogue sample is positive or negative. This method, known as symmetrical or folded binary, is preferred to straight binary, in which the scale of quantum steps is taken consecutively from maximum negative to maximum positive, as errors occurring in the most significant digits produce less clicks in low-level audio signals.

Quantization will inherently cause errors between the original signal and that recovered at the receive terminal. These errors appear as superimposed noise, but since this only occurs during speech a signal-to-noise ratio of about 25 dB

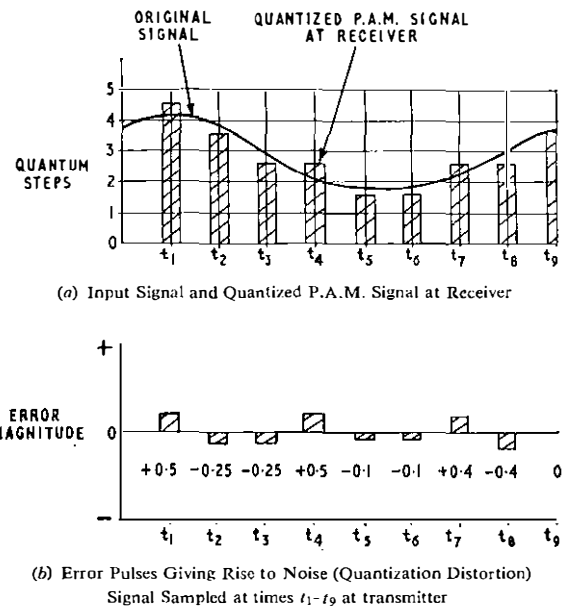


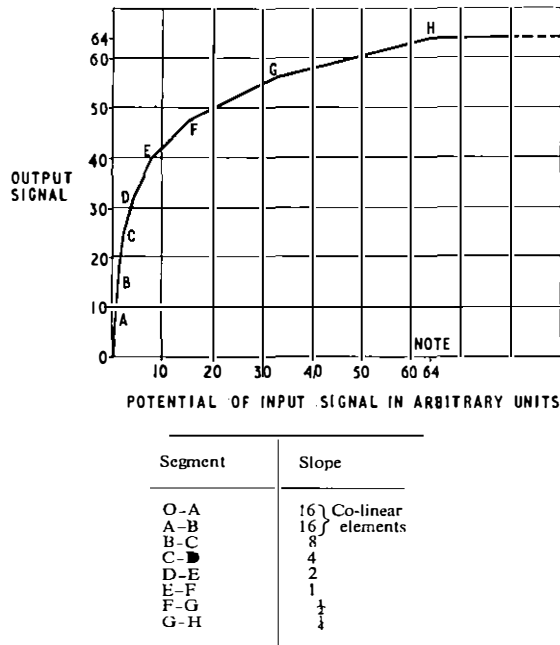
FIG. 3—Amplitude quantization of a signal

is acceptable. Fig. 3 shows how the quantized signal differs from the original and how the resultant errors are related to the two signals.

The system has to handle a dynamic range of 40 dB at the audio input. This allows for high-level and low-level speech and for the range of transmission losses which occur in the trunk, junction and local network between the system and the speaker. If the quantizing steps were arranged linearly either a very large number of steps would be required or low-level signals would have a poor signal-to-noise ratio. To avoid this, the steps are arranged in accordance with a logarithmic law which gives a constant signal-to-noise ratio over the whole dynamic range; this may be achieved either by using a compressor in front of a linear encoder to compress the range of incoming levels in accordance with the required law, or by

designing the coder on a non-linear basis. Both methods are used.

Methods to achieve approximation to the required logarithmic law have been the subject of much discussion, and that selected for the British Post office system is shown in



Note: An input of 64 corresponds to the peak of a sinusoidal input signal of +2 dBm0 at the 2-wire input of the circuit

FIG. 4—Compression law

Fig. 4. The maximum companding advantage of 24.1 dB gives an adequate signal-to-noise ratio for a connexion containing four separate analogue interconnected p.c.m.

systems. The selection of a 2:1 ratio for the slopes of the successive segments assisted the design of the non-linear coders.

At the output of the encoder, each channel amplitude sample is represented by a 7-digit binary number. Each channel time-slot has 8 digits available; the first is used to convey both the Strowger signalling information associated with the channel and synchronizing information to maintain the correct time and phase relationships between the transmit and receive multiplex terminals.

The complete set of digital information relating to one sample from all 24 channels is termed a frame. A group of n frames containing the information from $24n$ speech samples, together with ancillary information which only occurs once in the n frames, is termed a multi-frame (Fig. 5).

In the Post Office system, the multi-frame comprises four frames. The first digit of each channel in frames 1 and 3 is used to convey the Strowger signalling information; the first digit of each channel in frame 2 might be made available for data, e.g. as a 24×2 -kilobit channel. The first digit in channels 9-24 of frame 4 conveys the synchronizing signal.

Many arrangements of the digits available for synchronizing are possible, and the use of 16 in the selected pattern was influenced by the following considerations.

- (i) Unambiguous pattern recognition.
- (ii) Maximum immunity to disruption by an interfering noise signal.
- (iii) Speed of recovery after loss of synchronization.

To avoid the system searching, after a very short burst of errors, search is only initiated after three successive synchronizing patterns are found to be incorrect. Once search has been initiated, all channels are busied and the speech highway is disconnected at the receive terminal to prevent noise reaching telephones which may be connected to the channels. When the synchronizing pattern is restored, the system will recover in less than 7 ms.

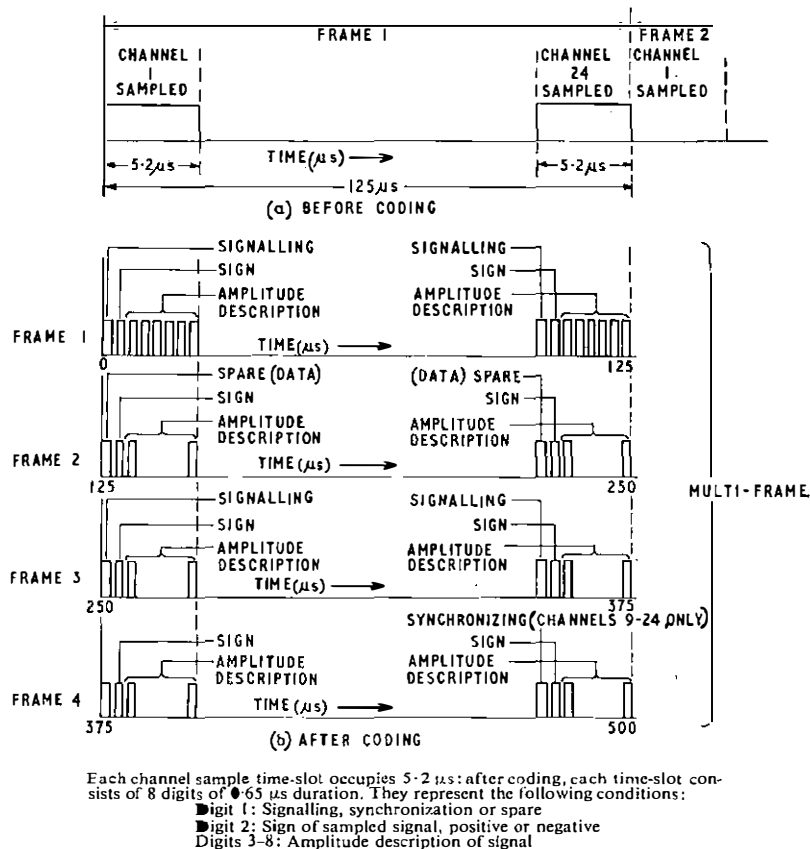


FIG. 5—Relative timing of signals in p.c.m. system

The assembled digital signal transmitted to line comprises 24 channels sampled at 8,000 samples/second, each sample requiring 7 amplitude-description digits and one signalling or synchronizing digit, giving a gross bit-rate of $24 \times 8,000 \times 8 = 1.536$ Mbits/second. Each bit could occupy a time of $0.65 \mu\text{s}$, but, as a 50 per cent duty cycle is used, the pulse width is only $0.325 \mu\text{s}$.

The final process before transmitting the signal to line is to convert the binary signal into a "bipolar" or "alternate mark inversion" signal by reversing the polarity of alternate marks, so that each mark has the opposite polarity to the previous mark. Such a signal has a negligible d.c. component and, thus, stabilizes the working point of the regenerator input circuit.

Alternate mark inversion should not be confused with "alternate digit inversion" which is the technique of inverting alternate digits in the binary numbers generated by the encoder. Alternate digit inversion, for speech signals, gives a pulse pattern with a higher density of marks and provides better timing information for the intermediate regenerators.

RECEIVE MULTIPLEX TERMINAL

The signal received at the multiplex terminal will normally be identical with that originally transmitted. The received signal is first restored to its unipolar form and the first digit in each channel time-slot is routed to the signal highway, data highway, or synchronization comparator as appropriate. The incoming digit stream is also used to generate timing information, as only the transmit multiplex has a master oscillator from which all the required timing waveforms are derived.

The expansion characteristic is the inverse of the compression characteristic, and the output of the expander on to the p.a.m. highway will be the quantized equivalent of the original pulse sample. This signal is passed through a low-pass filter, removing all the sidebands except that of zero frequency, d.c., which is the required audio signal. Other more complex methods of retrieving the audio signal are possible, e.g. pulse stretching. The 4-wire/2-wire terminations in the signalling units complete the circuits for connexion to the exchange.

Although compatibility can be obtained readily between two terminals of the same design, in which the compression characteristics and expansion characteristics are usually achieved by networks which are the inverse of each other, problems arise when it is necessary to obtain compatibility

between different designs. There are difficulties in defining the performance of the compressor/encoder and decoder/expander separately.

DIGITAL LINKS

The interconnexion of multiplex terminals and digital links requires compatibility. The digital link is connected to the multiplex via a standard interface of 75 ohms impedance (unbalanced) with a bipolar signal of 2.37 volts (equivalent to 3 volts in the nominal line impedance of 120 ohms). A 75-ohm unbalanced impedance was selected for the interface as this is convenient for patching and the connexion of test apparatus.

Line-terminal apparatus comprises an impedance-matching transformer in the transmit direction, a receive regenerator, and facilities for injecting d.c. power for the intermediate regenerators on to the centre points of two bearer pairs. So that the system is non-lethal, thus avoiding the need to provide personnel protection, the maximum permitted voltage on the line is 75-0.75 volts, current limited to 50 mA. This permits up to 9 regenerators to be fed from a terminal over 20 lb/mile cable.

Field-trial systems were designed to work over 20 lb/mile P.C.Q.T. cables, but there is no reason why other conductor weights or types of cable, such as unit twin, should not be used, and, because crosstalk is less, there are considerable advantages to be obtained from using this latter type.

Since a very wide bandwidth is required—compared with audio channels, for which such loaded cables are designed—it is first necessary to remove the loading coils from the cable. The usual loading-coil spacing of 2,000 yards is a convenient spacing for the pulse regenerators required. The insertion loss of such a cable section measured at 800 kHz is approximately 22 dB for 20 lb/mile P.C.Q.T. cable. Regenerators are fitted with an equalizer network at their inputs, and to enable a single regenerator design to be used on most types of cable, a range of equalizers is available.

The amplifiers required for an f.d.m. system not only increase the energy of the required signal, but also the energy of any unwanted noise. This is a cumulative effect, and is the basic reason why f.d.m. systems require either high-grade cables, which are relatively free from noise and have good crosstalk characteristics, or the use of syllabic compressors, which are expensive. A p.c.m. regenerator is a reconstructive device and may be considered to be a sophisticated descendant of the regenerative telegraph repeater, the p.c.m. line signal

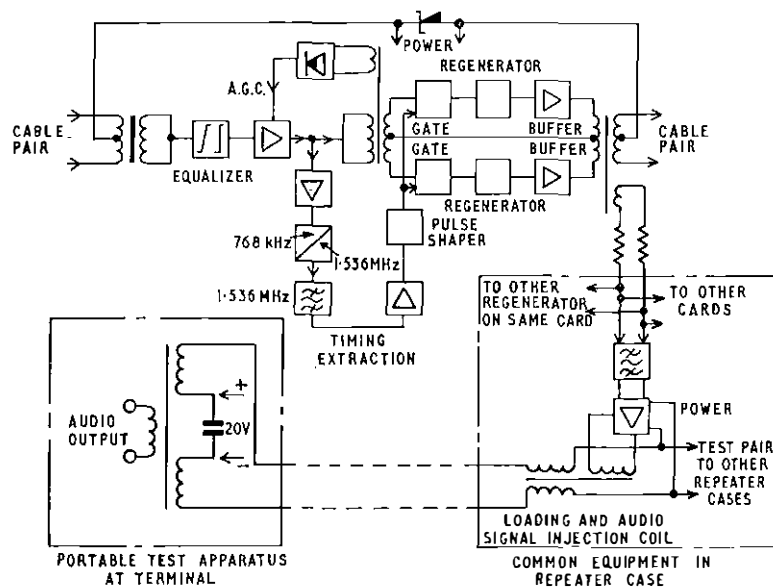


FIG. 6—Block schematic diagram of p.c.m. intermediate regenerator (one direction of transmission)

being likened to a telegraph-type signal. At each intermediate regenerator it is necessary only to determine whether or not a pulse exists in each time-slot and, if an incoming pulse is present, to generate a new pulse.

Since the cable acts as a low-pass filter, the original square pulses transmitted to line will be distorted at the end of the section and these pulses are first equalized and amplified to restore a symmetrical shape. A typical block schematic diagram of an intermediate regenerator is shown in Fig. 6, and pulse patterns (one mark, one space) at the output of a regenerator, at the end of 2,000 yards of cable, and after

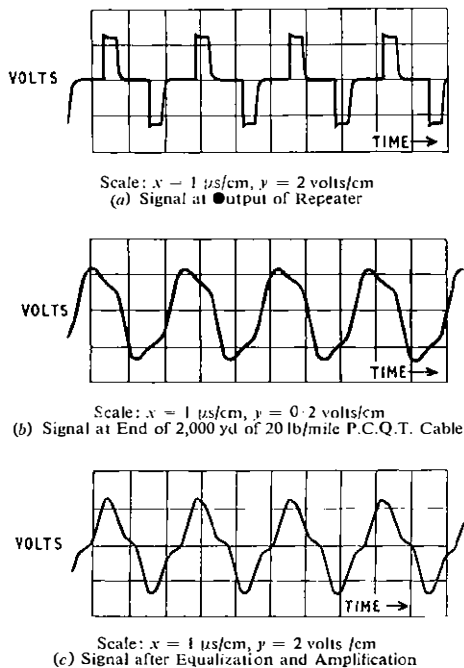


FIG. 7—Signal waveform at various points in digital link

equalization and amplification are shown in Fig. 7(a), (b) and (c), respectively.

After amplification the pulse pattern is used to drive a 1.536 MHz tuned circuit which provides the timing information for the gating circuits. The main signal path is connected to two gates, one for positive pulses and the other for negative pulses; the presence of an input pulse coincident with a timing pulse causes the appropriate regenerator circuit to produce a pulse of the correct polarity at the output. Automatic gain control (a.g.c.) is applied to the input amplifier to maintain the incoming signal at the optimum operating point of the gates.

As the regenerator timing is dependent on the line signal, there is a limit to the number of consecutive spaces that can be permitted, since, if the sequence is too long, the timing circuit will cease to function correctly. This precludes the use of line systems of this type for unrestricted data transmission, in which long sequences of spaces may occur.

Two complete regenerators sharing the same power-feeding source are mounted in a common container, the external connexions being made by means of a plug and socket. Twenty-four pairs of regenerators can be accommodated in a Case, Repeater Equipment (C.R.E.), No. 1, and the connectors for these are wired direct, via a tail cable which enters the C.R.E. No. 1 through an epoxy-resin seal that forms part of an airtight gland assembly fitted in one of the entry holes.

For fault-locating purposes the regenerators each have an auxiliary output which is commoned, by means of masking resistors, to an audio band-pass filter and an amplifier whose output is connected to a fault-locating pair common to all

the repeater cases on a particular route. Each repeater case is allocated a discrete audio frequency which is common for all the regenerators in that case.

SYSTEM MAINTENANCE

As p.c.m. systems will largely replace or supplement circuits which have hitherto been provided either as un-amplified or 2-wire amplified circuits, a high degree of reliability is required if the same standards are to be achieved. Adequate alarm facilities must be provided without unduly burdening the system with complicated and expensive circuits.

When a fault occurs the fault is first proved to be on the link or in the multiplex by patching in a spare link.

If the link is faulty, a pattern generator, which produces digits in groups of three, is connected to the link and the pattern is inverted at an audio rate corresponding to the frequency allocated to the regenerators in the first repeater case. If the regenerator functions correctly the appropriate audio frequency will be derived by the audio filter and can be detected on the common fault-location pair at the terminal station. The audio frequency is successively changed until the faulty regenerator is located by its failure to produce its appropriate audio frequency. The margin of the regenerator can also be checked by increasing the density of the groups of digits, thus driving the regenerator further from its normal working point by increasing the d.c. bias of the signal.

If the multiplex is faulty, in-station looping of the transmit to the receive pairs will locate the fault to transmit or receive apparatus. Successive substitution with spare cards will provide the final identification of the faulty card. Apart from minor faults, maintenance will not be carried out in the field, faulty items being dealt with at fully-equipped repair centres.

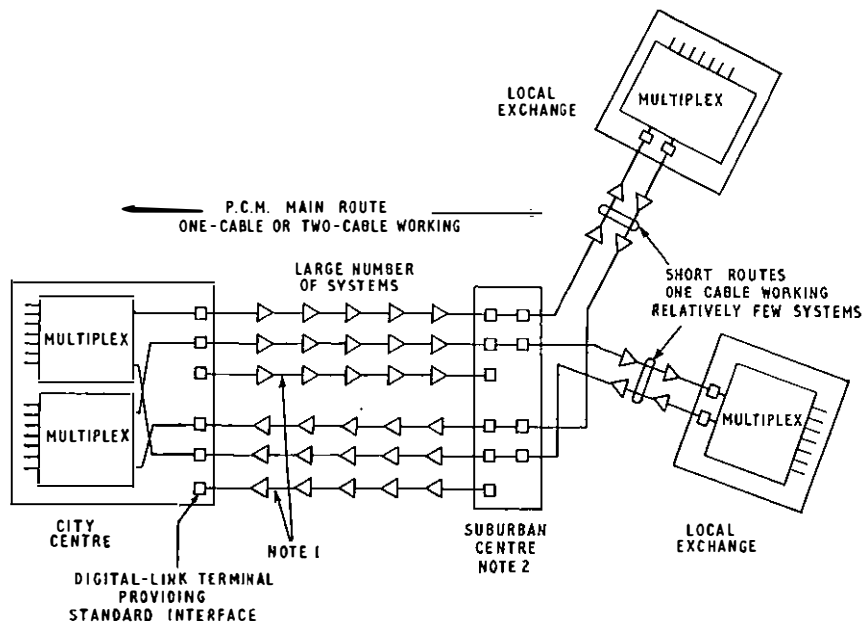
Alarms are not provided on the line link since failure of the digital path will produce a fault indication on the multiplex apparatus. The multiplex is provided with alarms to indicate loss of synchronization, loss of digital signals, high error-rate and power-supply failure. In addition, it is necessary to provide a monitor on the common transmission path since the encoder and decoder and the p.a.m. highways can fail independently of the signalling and synchronization highways.

Although it is inevitable that a large number of components common to all 24 channels are used in each system, it is expected that the wide use of silicon semiconductors and groups of components assembled as monolithic devices will give highly reliable systems. Cable faults may still be the cause of the majority of system failures.

EFFECTS OF NOISE AND CROSSTALK

Although the digital link is robust and will function satisfactorily in a noise and crosstalk environment which would prevent the use of f.d.m. systems there is, nevertheless, a problem in determining the number of systems that can function in a given cable with an acceptable error-rate when subject to crosstalk effects. The situation is worsened when the regenerators are in the vicinity of an exchange where impulsive noise reduces their working margin. Pulse-code modulation has a great advantage in that the effect of line noise is not cumulative, and, provided that the noise is not sufficient to cause false recognition and regeneration of pulses, the distortion on the channels is due entirely to effects occurring within the multiplex terminals. As a result of studies of cable-crosstalk parameters, rules are being evolved which will permit planning engineers to determine the number of p.c.m. systems permissible in any particular cable.

To minimize the effect of exchange noise it is planned to install the regenerators at receive ends of links at 1,000 yd from the terminal exchanges, instead of the 2,000 yd that is the standard spacing between regenerators. Suitable adjustments of the spacing are made in the vicinity of spur cables to other exchanges.



Note 1. Spare system which can be patched in to restore service to any faulty system on main route
 2. Multiplex equipment may also be provided here

FIG. 8—Possible arrangement of p.c.m. systems

NETWORK PLANNING

Considerable care is needed at the planning stage if the full advantages of p.c.m. are to be exploited.⁴

In areas other than those where a few isolated point-to-point systems are required it is expected that the network of p.c.m. systems will develop along the lines shown in Fig. 8. This permits digital links to be provided independently of the multiplex terminals, and provides facilities for the interconnexion of line links and the patching out of faulty digital links at the terminal stations. A standard interface is thus necessary at these points to provide flexibility between systems together with testing facilities.

FUTURE DEVELOPMENTS

Future developments may be divided into three categories:

- (i) extensions of the use of the existing design of system,
- (ii) application to digital exchange networks, and
- (iii) new designs.

Under (i), it might be possible to make use of the spare first digit in each channel of frame 2 of the multi-frame (Fig. 5(b)) for telegraph data. In the interests of economy, only one common highway needs to be provided on the p.c.m. terminal. The necessary gating apparatus for individual channels would have to be made available as separate items.

Experiments have demonstrated the feasibility of using digital links for the transmission of high-speed black-and-white dot-density facsimile, such as is required for remote reproduction of newspapers. Speeds of transmission at least as fast as those achieved over a 240 kHz f.d.m. band are possible, without the associated problems of group-delay equalization and the provision of special coaxial local-ends to the subscribers' premises.

Digital transmission of this type of data offers considerable advantages—for example, discrete codes can be allocated to dots of various colours, thus facilitating colour transmission. The use of digital line-links to provide access circuits to computers is another possibility.

(ii) The use of p.c.m. systems in conjunction with digital tandem exchanges has been one of the factors taken into account in determining the specification for the standard British Post Office system. The success of digital tandem exchanges could considerably influence the rate of growth

of systems in the junction network, although it is expected that p.c.m. will have a considerable field of application irrespective of the integration of exchange and line p.c.m. systems.

(iii) New designs will achieve much higher transmission speeds, and in the United States experimental systems at line speeds of 224 Mbits/second are being explored. In addition to telephony, such systems are capable of carrying television and picture-phone circuits. The transmission medium might be a cheaper version of 0.375 in. coaxial cable with regenerators at about 1-mile intervals.

CONCLUSIONS

The essential features of p.c.m. have been outlined. Work already done has proved that the system is capable of providing speech channels of a better quality than those using loaded audio cable. The availability of inexpensive semiconductor devices and other modern components of high reliability has given impetus to the development of p.c.m. systems which have, for the junction network at least, a number of advantages compared to their f.d.m. counterparts. When digital exchanges, into which p.c.m. junction systems can be integrated, become a practical reality, the economics will become even more pronounced and transmission will be improved since it will be possible to provide connexions having a predetermined loss, e.g. 3 dB, when set-up via a tandem exchange.

It may well be that the p.c.m. junction system described represents the start of a new era in the provision of telephone service, in which signalling facilities are no longer as restricted as they have been hitherto and in which the degradation of quality no longer rises in proportion to the length of the connexion.

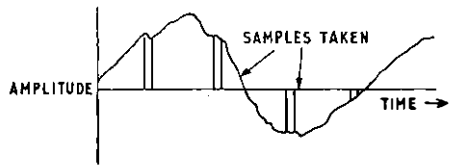
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- 4 JEYNES, E. Planning and Works Aspects of 24-Circuit Pulse-Code-Modulation Systems. *P.O.E.E.J.*, Vol. 60, p. 33, Apr. 1967.

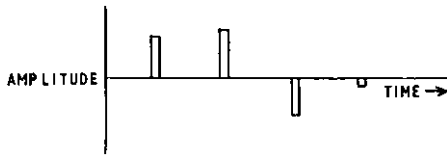
APPENDIX

Sampling considered as a modulation process

In pulse-code modulation, samples of a waveform are taken periodically as shown in Fig. 9.



(a) Waveform with Sampling Pulses Superimposed



(b) Resulting Pulse-Amplitude Samples

FIG. 9—Sampling a waveform

An alternative way to look at the sampling process is to say that the signal waveform is modulated by a unit-amplitude positive-pulse waveform as in Fig. 10.

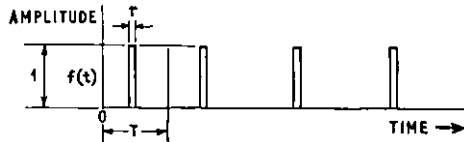


FIG. 10—Unit-amplitude pulse waveform

The average, or d.c., value of such a waveform is τ/T or A_{av} . Analysing the pulse into its Fourier components,

$$f(t) = A_{av} + 2A_{av} \sum_{n=1}^{n=\infty} \left[\frac{\sin n\pi \times \frac{\tau}{T}}{n\pi \frac{\tau}{T}} \right] \cos \frac{2\pi nt}{T},$$

where $n = 1, 2, 3$, etc.

For a 24-channel p.c.m. system, $\tau = 3 \mu\text{s}$, $T = 125 \mu\text{s}$ and so

$$\left[\frac{\sin n\pi \frac{\tau}{T}}{n\pi \frac{\tau}{T}} \right] \text{ is very nearly unity for all low values of } n.$$

Therefore, $f(t) \approx A_{av} + 2A_{av} \sum_{n=1}^{n=\infty} \cos \frac{2\pi nt}{T}$.

If now a signal $B \cos pt$ is modulated with $f(t)$,

$$f(t) B \cos pt = A_{av} B \cos pt + 2A_{av} B \sum_{n=1}^{n=\infty} \cos pt \cos \frac{2\pi nt}{T}.$$

Now, let $\omega = 2\pi/T$. Then,

$$f(t) B \cos pt = A_{av} B \cos pt + A_{av} B \sum_{n=-1}^{n=\infty} \cos (n\omega + p)t + \cos (n\omega - p)t.$$

In general, only very low values of n are of interest—often only $n = 1$ need be considered.

If instead of a single frequency p the signal comprises a band of frequencies p_1 to p_2 the component frequencies of the modulated signal, i.e. the p.a.m. pulses, can be plotted as in Fig. 11.

ω and 2ω are not actually present except in the absence of a signal, i.e. when $p_1 = p_2 = 0$.

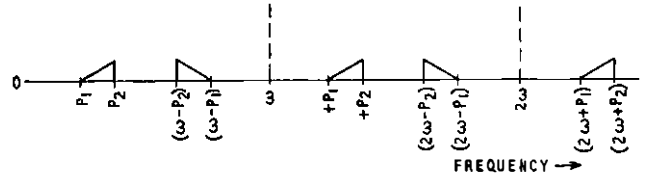


FIG. 11—Component frequencies of the modulated signal

From Fig. 11, the conditions that have to be satisfied in order that the signal can be easily recovered are determined as follows.

(a) To recover the signal by simple low-pass filtering $\omega - p_2 \geq p_2$ or $\omega \geq 2p_2$. This is the well-known "sampling frequency must be at least twice the highest signal frequency."

(b) In some cases it can be arranged that the lower sideband of the sampling frequency falls below the signal band. For this to be possible two equations $(\omega - p_2) \geq 0$ and $(\omega - p_1) \leq p_1$ have to be simultaneously satisfied. Let $p_2 = kp_1$ and then, substituting for p_2 in the first equation, $\omega \geq kp_1$ and, rewriting the second equation, $\omega \leq 2p_1$. Thus $2p_1 \geq kp_1 \geq k$, i.e. for such a condition to apply the frequency band of the signal must not extend over a range greater than 2:1, one octave.

A typical practical case is that of a group band, i.e. 60 kHz to 108 kHz = p_2 .

$$\text{Here, } \omega - 108 \geq 0$$

$$\text{and } \omega - 60 \leq 60.$$

Thus, any frequency of sampling between 108 kHz and 120 kHz is satisfactory. If the mean value is 114 kHz, the sideband will extend from 6–54 kHz, the 6 kHz corresponding to p_2 and 54 kHz corresponding to p_1 .

If a group band of 60–108 kHz is sampled at 114 kHz and transmitted, the 6–54 kHz sideband can be extracted by a low-pass filter and the original signal can be recovered by modulation with a carrier of 114 kHz and filtering, as shown by Fig. 12.

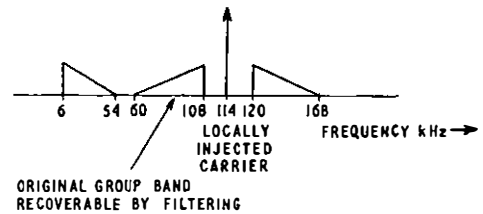


FIG. 12—Recovery of an original group-band by demodulating and filtering an f.d.m. signal

United Kingdom Seminar on Communication-Satellite Earth-Station Planning and Operation

U.D.C. 621.396.7: 621.396.934.004.1

During May 1968 a Seminar was held in London on the planning and operation of communication-satellite earth stations. Sponsored by the United Kingdom Government and Industry it attracted some 126 representatives of 55 overseas administrations and 120 from United Kingdom organizations.

A Seminar on the planning and operation of communication-satellite earth stations, which was held in London for 2 weeks from 20 May to 31 May 1968, was sponsored by the United Kingdom Government (Post Office and Ministry of Technology) and Industry (Cable and Wireless, Ltd., Crown Agents for Overseas Governments and Administrations, Elliott Automation, G.E.C.-A.E.I. (Electronics), Ltd., Husband and Co., Mullard, Ltd., Plessey Radar, Ltd., and the Marconi Co., Ltd.). It obtained world-wide publicity through the International Telecommunications Union (I.T.U.) and overseas technical press, and, as a result, some 126 representatives from 55 overseas administrations and operating agencies attended, in addition to 120 representatives from organizations in the United Kingdom. The Seminar was organized by a committee of the sponsoring agencies, with the Post Office providing the Chairman.

The Seminar was opened by the Postmaster-General, the Right Honourable Roy Mason, M.P., in the Derby Room of the Royal Lancaster Hotel. Also present at the opening ceremony were Mr. H. Ruud, Head of the Department of Technical Co-operation, I.T.U., Mr. J. C. Nichols of the Audio and Visual Services Department, United Nations, and Mr. H. Stanesby, Chairman of the Consultative Committee on Satellite Telecommunications, together with senior members of the organizations sponsoring the Seminar. The Post Office was represented by Mr. J. H. H. Merriman, O.B.E., Senior Director of Development, Telecommunications Headquarters.

For the first week of the Seminar delegates met at the Royal Lancaster Hotel to hear and discuss a total of 29 papers dealing with the planning, design, provision and operation of communication-satellite earth stations. Eight of the papers were presented by members of the Post Office, the remainder being contributed by the other sponsors; for the benefit of overseas delegates an instantaneous translation service on headphones was provided in French and Spanish.

An exhibition arranged by the Committee sponsoring the Seminar was also held during the first week, in a room at the hotel adjacent to the conference room. The Post Office Public Relations Department was responsible for the overall organi-

zation of the exhibition and for the detailed presentation of the Post Office stand which illustrated, with photographs and models, the developments in earth-station design pioneered by the British Post Office. Staff of the Space Communications Systems Branch, Telecommunications Headquarters, were present each day on the Post Office stand and the Crown Agents stand to answer technical queries.

For the second week of the Seminar, visits were arranged to various establishments in the United Kingdom. These included the laboratories and factories of the sponsoring firms, the Post Office Tower, the International Telcx Exchange, Jodrell Bank Radio Observatory and the Post Office Earth Station at Goonhilly, Cornwall. The latter visit was very popular: about 120 of the overseas delegates electing to take part, and, to enable the visit to be completed in one day, a 132-seat Britannia aircraft was chartered to carry delegates between London Airport and the Royal Naval Air Station at Culdrose, which is only about 3 miles from Goonhilly. For the first part of the day at Goonhilly delegates were shown round the No. 1 aerial, which was operating the transatlantic telephone service through the Intelsat I satellite, by guides from the External Telecommunications Executive station staff and from Telecommunications Headquarters. In the afternoon, following a buffet lunch in the station's newly-opened staff restaurant, representatives of the Marconi Co., G.E.C.-A.E.I. (Electronics), Ltd., and Husband and Co., conducted delegates over the station extensions and the partly-completed No. 2 aerial, which are being built for use with the Atlantic Intelsat III satellite to be launched later this year.

It is the hope of the Organizing Committee that those attending the Seminar found it both instructive and interesting. If this was achieved it was due in no small measure to the help given by Post Office staff at all levels, and the Organizing Committee wishes to express thanks to them all. From the point of view of the Committee it was an interesting example of a joint Government and Industry project which moulded together many different interests into a unified and successful venture.

R. E. G. B.

Electronic Telephone Exchanges: Speech-Path Control in Reed-Electronic Exchanges

J. TIPPLER, R. C. LONG, C.ENG., M.I.E.E., and D. F. RIGBY†

U.D.C. 621.395.345: 621.395.722

The underlying principles of speech-path control are the same in all reed-electronic exchange systems developed for British Post Office use. Differences of technique arise from the differences in size and traffic capacity of the controlled switch networks. This article describes the principles of path-selection by the twin processes of interrogation and path choice, the methods of path marking, and the traffic-limiting effect of path-control equipment. Following a section on miscellaneous path-control functions, the article concludes with an indication of possible future developments.

INTRODUCTION

A previous article* described the need for, and some different approaches to, the control of path selection in reed-electronic systems, and outlined the nature of the switching network in these systems. The purpose of the present article is to discuss the salient features of path control in the reed-electronic systems which have now reached, or are approaching, the stage at which production for British Post Office use is possible. The systems that have been developed are TXE2 for small exchanges, TXE3 for large exchanges, TXE4, which is a cost-reduced version of TXE3, and TXE6, which is an experimental system primarily intended for extension and replacement of Strowger exchanges but which could be used to provide complete new exchanges.

A brief review of the nature of these systems will provide a useful background to the sections that follow.

TXE2, TXE3 and TXE4 are full-common-control systems. That is, the control area of each of these exchanges, which receives and processes instructions from subscribers' dials and other sources, is common to the whole switching network of the exchange. A path is not set through the network until the common-control has received enough information to identify the network terminal points between which connexion is required, after which it issues instructions to cause the setting of the complete path at one operation through all stages of the network.

The TXE6 system, on the other hand, being designed particularly for use in Strowger extensions, embodies stage-by-stage selection principles, though, compared with Strowger, TXE6 is a much more powerful system offering a greatly enhanced switching capability. The switching network of TXE6 is contained in two types of units: one provides, electronically, the broad equivalent of 96 200-outlet group-selectors, the other the equivalent of a final-selector stage catering for between 75 and 1,050 subscribers, depending on the average traffic per line. Each unit has its own self-contained control equipment, known as a "stage control." Dialed instructions or their equivalent are passed along the speech path to successive TXE6 stage controls, much as Strowger pulses are passed along the speech path to successive selectors in an electromechanical exchange, but using a faster, higher-order, signalling technique.

In all four systems, a basic part of the switching network is a 2-stage fully-interconnected network element, the principle of which is illustrated in Fig. 1. Each switch in each stage is

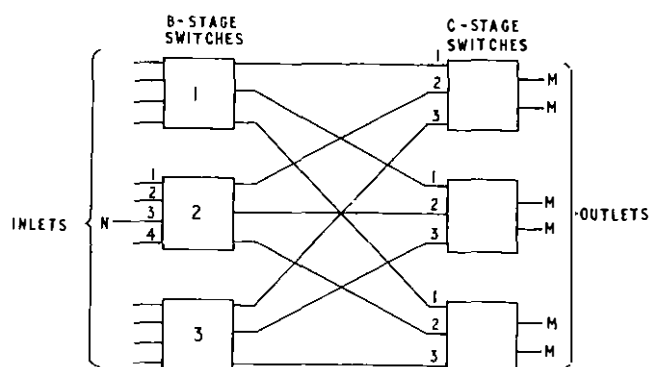


FIG. 1—Two-stage fully-interconnected network element

connected by one trunk only to each switch in the other. It can be seen that to reach a required point, N, from any of the points M, the same pair of selection digits is always used (2 and 3 in the example shown). Thus, with respect to the points M, point N has a unique identity, a useful feature which greatly simplifies path control. For example, if point N is a subscriber's line and points M are connected to call-supervisory circuits, the subscriber may be connected to a supervisory if the direct switch controls receive simply the identity of the free supervisory and the unique identity of point N.

The 2-stage network elements are of different sizes and are used in slightly different ways in the different systems. In TXE6, the 2-stage element appears in each type of switch unit, and points such as N and M are connected to preceding and succeeding selector stages. In TXE2, TXE3 and TXE4 the 2-stage elements are augmented by one, and sometimes two, other switching stages. The first of these is a line-concentrator stage which permits traffic from subscribers' lines to be concentrated in suitable degree for the 2-stage network. In TXE3 and TXE4, the additional stages are added without loss of the principle of unique identity, though, of course, this now involves more digits.

The equipment location of a called line in a Strowger exchange may be identified from its directory number. In TXE2, TXE3 and TXE4 the directory number does not correspond directly with the switch outlets used, and for

† Electronic Exchange Development Branch, Telecommunications Development Department, Telecommunications Headquarters.

* MARTIN, J. *Electronic Telephone Exchanges: An Introduction to Switching Network Design*. P.O.E.E.J., Vol. 60, p. 124, July 1967.

control purposes another identity, the equipment number, is used.

There are various differences in the path-control techniques of the four systems. Some, being minor and not affecting the principle described, are not brought out here. For example, marking is illustrated by reference to TXE2; the other systems differ in respect of potentials used and order of switch operation, but these differences will be obvious to anyone studying the systems in detail and are not discussed. A further point is that the application of the terms "inlet" and "outlet" to the reed switches differs among the systems, inlets being sometimes nearer to the periphery and sometimes nearer to the centre of the exchange. Although there are sound reasons for the differences, this article adheres to a single method only, in the hope of avoiding confusion. It will thus be at variance with the detailed working documents of some systems. Certain other terms will also be found to differ slightly among the systems, but these are unlikely to cause subsequent difficulty and are not commented on here.

PATH SELECTION

Path selection can be broken down into two processes: path inspection (or interrogation) to determine which paths through the switching matrices are free, and the subsequent choice, according to defined rules, of one suitable path from the many which may be available.

Interrogation

Each connexion through the switches consists of three or four wires: the negative and positive speech-wires, the H-wire to hold the cross-point relays, and, if required, a P-wire or S-wire for control-signal purposes. In all four systems the H-wire is used for interrogation as this is the only wire free from external variable conditions.

The electrical techniques used for interrogation are strongly dependent on the speed at which interrogating operations must be completed. In the TXE2, TXE3 and TXE4 systems, several interrogations may be required during the setting-up of a call. Each of these involves simultaneous inspection of all switching stages from end to end of a desired connexion, and interrogating operations can take place only one at a time per exchange; examples of desired connexions are subscriber to register, register to auxiliary equipment, and calling subscriber to called subscriber. A TXE2 (small) exchange may carry out up to 14,000 interrogations in the busy hour, while a TXE3 or TXE4 (large) exchange may handle more than half a million. In TXE6 the stage controls are responsible for interrogation, each stage control acting independently of the others and for its own unit only, and a stage control is not required to carry out more than 2,000 interrogations in the busy hour. For TXE2 and TXE6, therefore, relatively low-speed working is adequate, but, for TXE3 and TXE4, high speed is essential. These differences lead to different optimum ways of meeting the requirements economically.

In all four systems, interrogation involves the sampling of potentials on the H-wires of indicated switch inlets and outlets to determine whether they are free or busy, and some form of voltage-discriminating circuit must be used. TXE3 and TXE4 have very large switching networks to provide maximum traffic capacities of between 2,000 and 8,000 Erlangs, and the networks are divided for security and switch-size economy into units and sub-units. The physical distances separating these from the exchange common-control, and the speed at which interrogation must be carried out, make it electrically desirable to separate the voltage-discriminators from the common-control and to locate them close to the parts of the switching network they serve. Each sub-unit of the network therefore has its own interrogator, which contains the discriminators and other related equipment, all the interrogators being linked to the common-control by a highway signalling system. With the timing constraints

of the large exchanges it is not possible for information to be extended continuously from the common-control for the duration of the interrogation. When interrogation is required, switch inlet and outlet identities and other information are signalled from the common-control to stores in the appropriate sub-unit interrogators, where they are held until interrogation is complete.

In TXE2 the designed maximum exchange traffic capacity is 240 Erlangs, and it is possible for the whole switching network of the exchange to be served by a single interrogator (duplicated for security). The lower operating speeds and smaller physical size of the exchange make it electrically convenient to place the interrogator with the rest of the exchange control equipment, and separate local storage of digital information in the interrogator is unnecessary. In TXE6 the interrogating function is carried out by the stage control. This is always mounted close to its associated switches, and no special signalling or storage problems arise.

The low-speed requirements of TXE2 and TXE6 have led to the use of a common voltage-discriminating element per interrogating function, and this is relay-switched to indicated inlets and outlets during interrogation. Fig. 2 shows, by way

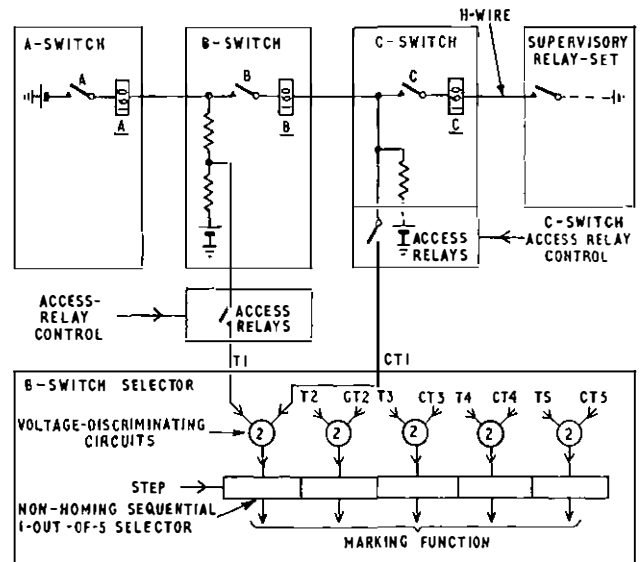


Fig. 2—Small-exchange interrogation and path-choice arrangements

of example, the method used in TXE2. The access relays are operated from marking relays associated with the network terminal points between which connexion is required, and these, in turn, are operated by signals maintained continuously by the common-control for the duration of the interrogation. Different terminal points would require interrogation of different switch inlets and outlets by operation of different access relays. The discriminating circuit will indicate "free" when a positive potential is seen, and "busy" when negative, the negative potential being produced when hold current is flowing in the cross-point relay coils. An absence of the positive bias potential, as when a switch is removed from the rack, is also taken as a busy condition. Reed relays are used for the access function because they have adequate speed and life, and are relatively cheap.

Fig. 3 shows the corresponding arrangement in the TXE3 and TXE4 systems. Speed requirements prevent the use of switched voltage-discriminating circuits: instead, each switch inlet or outlet which may be interrogated has a permanently-connected pulse-plus-bias gate (shown in detail in Fig. 4), and this gate acts as the discriminator. When interrogation is required, the identities of the inlets and outlets to be interrogated are received from the common-control in the form of the equipment numbers of the network terminal

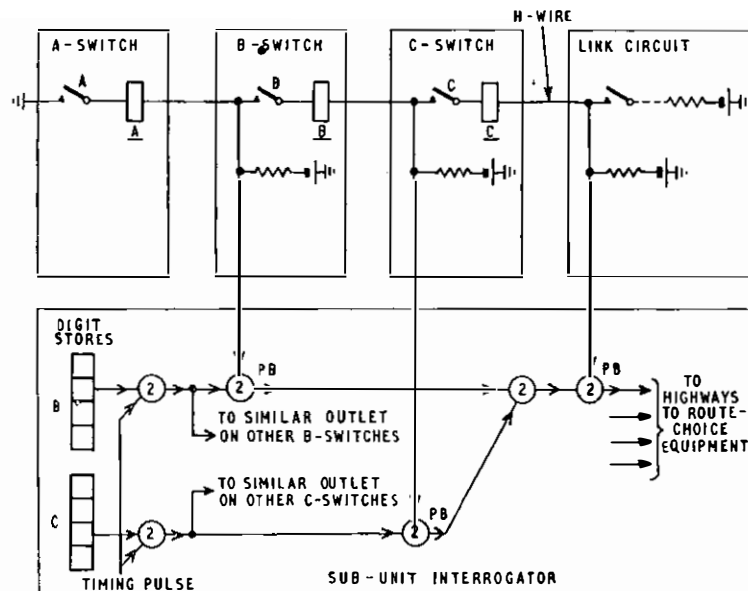


FIG. 3—Large-exchange interrogation arrangement

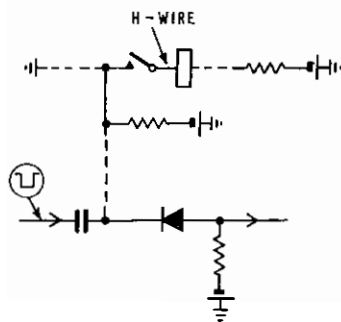


FIG. 4. Pulse-plus-bias gate

points concerned. This information is stored on electronic-toggle digit stores, whose outputs allow pulses to be gated to all appropriate pulse-plus-bias gates simultaneously, and an output pulse will appear from each pulse-plus-bias gate whose associated H-wire is free. When the H-wire is busy, the potential is such as to keep the diode (Fig. 4) back-biased when the pulse occurs, so that no output pulse is given. This technique is more expensive than using relay access to the H-wires, but it is justified by the need to work at high speed in relation to the system as a whole and by the fact that the interrogate function is more intensively used in TXE3 and TXE4 than in the other systems: since more paths are available for any single connexion, and all are investigated during interrogation, it follows that any given switch inlet or outlet is interrogated on behalf of more connexions than is the case in TXE2 or TXE6. The life of the interrogating elements, in terms of the number of operations, must therefore be high.

In all systems the interrogation will have produced an indication of which paths in particular parts of the switching network are free. These may be many, and just one must be selected for use.

Path Choice

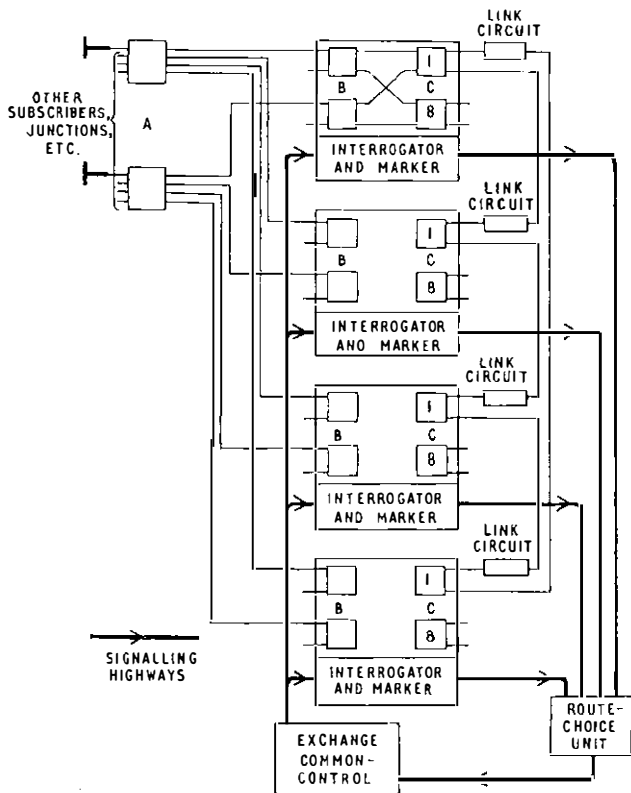
In both TXE2 and TXE6 only one interrogator will be concerned with an interrogation, and the path-choice mechanism is directly associated with, and almost part of, the interrogator.

In a typical TXE2 call-selection operation the common-control first instructs a C-switch selector to choose a C-switch that has a free supervisory relay-set connected to it. The C-switch access-relay contacts (see Fig. 2) then close, and the

B-C link test wires (CT 1-5) are connected to the path-choice equipment (B-switch selector). At the same time, the five A-B links associated with the subscriber are also extended to the B-switch selector. The path-choice equipment now chooses complementary A-B and B-C links, i.e. one complete A-C connexion between the subscriber and the selected C-switch. This is achieved by a non-homing sequential 1-out-of-5 selector which consists of interconnected diode gates and memory elements. When the selection has been made, and the information signalled to the marking function, the selector takes one step. This ensures that if the selected connexion is faulty a different path can be selected when an automatic second attempt is made to set up the call.

In the large exchanges, TXE3 and TXE4, an interrogation for a single connexion may have covered up to 16 or 20 sub-units, each with its own interrogator (out of an exchange total which may, in TXE4 at any rate, exceed 100). No single interrogator knows more than a part of the result of the interrogation, and it is necessary for the several interrogators to signal their individual results to some common point where the total situation can be assessed and a choice made. At present, this common point is the route-choice unit, a separate equipment with signalling highways from the interrogators and to the exchange common-control. Typical highway interconnexions between common-control, interrogators, and route-choice unit are shown in Fig. 5, which also shows that switching sub-units are interconnected by link circuits joining outlets on like-numbered C-switches.

A path between two network terminals will be set from one terminal via A, B, and C switching stages, through a link circuit, via C, B, and A switching stages of a different sub-unit, and to the second terminal. (In TXE4, there is a further switching stage, D, between one C stage and the link circuit.) At the end of the interrogation, each interrogator can identify those link circuits from which paths are available through its own sub-unit to the required terminals. These identities are signalled to the route-choice unit, which selects just one path for use. It does this in three stages: first, it considers only link circuits which have, in each instance, been indicated as available to both sub-units concerned; second, it prefers link circuits connected to lower-numbered C-switches and it takes those on the lowest possible number; and, third, if circuits on a given C-switch number are available on more than one link route, it makes a random choice of the route to be used. This process isolates one single link circuit to be used and, because of the unique-identity characteristic of the network described earlier, that implies a unique cross-point path



- Notes: 1. The figure shows a single switching unit with four sub-units. There may be many switching units in an exchange, each with four to 10 sub-units. Different switching units are interconnected by link circuits.
 2. A group of links interconnecting two sub-units is known as a link route. Only one link of each route is shown here.
 3. Common-control and route-choice units are replicated for security.

FIG. 5—TXE3 speech paths and signal highways

between the terminals for which connexion is required. The identity of the chosen link circuit is signalled from the route-choice unit to the exchange common-control, from which, together with the equipment numbers, i.e. network terminal identities, of the points to be connected, it can be signalled to the markers which will operate the required switch cross-

points. Packing of the calls, in this instance to lower-numbered C-switches, enhances the traffic capacity of the system. The random choice of link route increases system security since, if a connexion fails at the first attempt and an automatic second attempt is made, there is a good chance that a different link route will be selected on the second occasion: thus, possibly-faulty switch paths or markers are avoided. The degree of security may be even further improved by causing the route-choice to prefer higher-numbered rather than lower-numbered C-switches at the second attempt.

MARKING

Having selected a path, the next step is to operate the reed-relay cross-points that will establish it. This process is known as marking, and in all four systems the marking function is closely associated with, and provided at the same rate as, the interrogating function: one per exchange (duplicated for security) in TXE2, one per switching sub-unit in TXE3 and TXE4, and one per stage control in TXE6. Where possible, circuits are often shared with the interrogating function. For example, in TXE3 and TXE4 the digit-storage elements are common.

The marking equipment needs to know the identities of the two peripheral points to be connected through the network for which it is responsible. In TXE6 these will be the inlet at which a call entered from the previous selector stage and the outlet selected by the path-choice operation of the stage control. In TXE2, TXE3 and TXE4 one point will be a calling or called subscriber, junction, etc., and the other will be a supervisory or link circuit chosen by the path-choice equipment.

Marking requires the application of potentials to the selected switch inlets and outlets which will cause the operation of a single cross-point (reed relay) at each switching stage. No other cross-points must operate, and there must be no interference with existing calls passing through the switches which are being marked. Furthermore, marking conditions must not be applied to an outlet already carrying a call or double connexion will occur: only one cross-point may be operated in each column or row of the switch matrix. The technique used is very much the same in all four systems, and is illustrated in Fig. 6, which happens to relate to the small exchange, TXE2. Here, the +15-volt and +7.5-volt

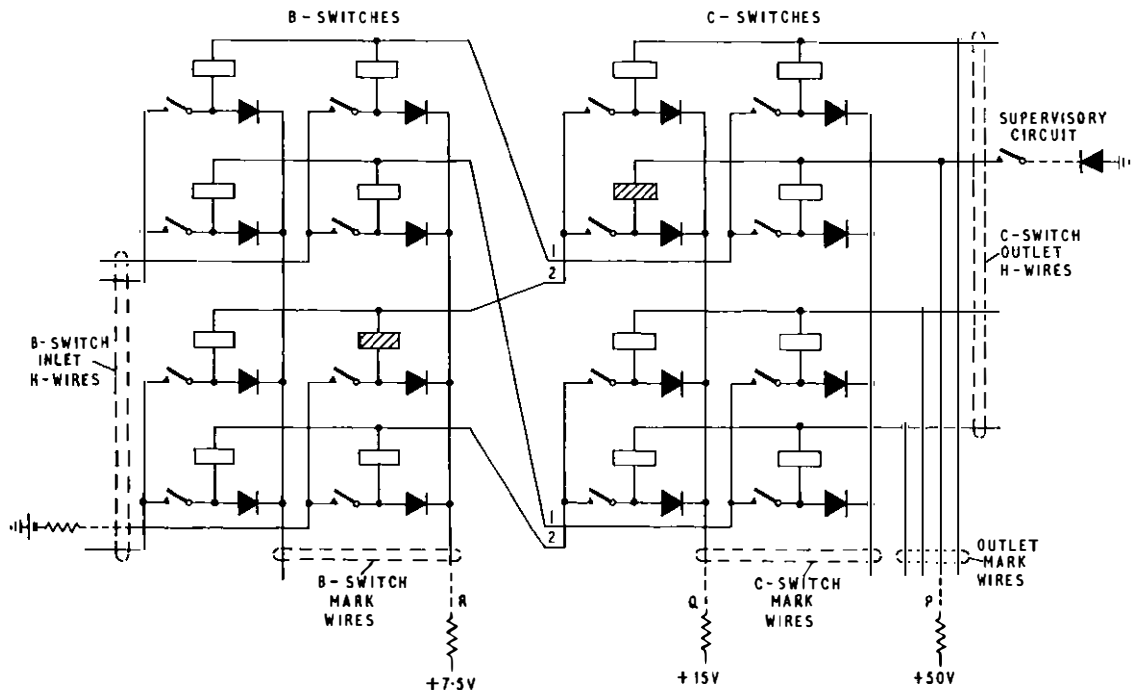


FIG. 6—Small-exchange marking arrangement

potentials are applied by relays operated according to the identity of the network terminal (e.g. subscriber's line) to which a path is being set, while the +50-volt potential is applied by a relay contact to a point such as a link or supervisory circuit which has been selected by the path-choice operation. In the example shown the shaded cross-point relays will operate, the +50-volt marking potential being extended to the B stage when the C-stage cross-point has operated. After operation, the cross-points are held from the supervisory circuit under the control of the subscriber's loop.

As shown in Fig. 6 each of the +15-volt and +7.5-volt marking wires (such as Q and R) is common to a large number of switch inlets, and it is necessary to provide a diode per cross-point to isolate the separate H-wires from each other. The diodes also serve to prevent the marking potentials from reaching the H-wires of established connexions. For this purpose, marking potentials are in a separate voltage range from holding potentials so that a diode connecting a marked wire with a busy H-wire will be non-conducting. In all four systems, holding potentials are in the range earth to -50 volts, whereas marking potentials are either more positive than earth or more negative than -50 volts. There is a large number of cross-point diodes in an exchange, and failure of any one of them could cause double-connexion trouble which might be difficult to locate. This may be prevented by causing a marker to check for short-circuit or low-back-resistance diodes at each marking operation, and to indicate when a fault is found.

TRAFFIC-LIMITING EFFECT OF PATH-CONTROL EQUIPMENT

Path-control equipment is common equipment, used on behalf of many separate call set-ups, and, since it takes time to operate, there is a limit to the number of call set-ups which can be handled.

In TXE2 each whole operation of interrogation, path choice, and marking is performed one-at-a-time per exchange and takes 50 ms. Assuming that two such operations are required per call, and that the achievable occupancy of this equipment is 0.2, it would be possible for $3,600 \times 1,000 \times 0.2/50 \times 2$, i.e. 7,200, calls to be handled in the busy hour. This is more than adequate to meet the system specification.

The holding time of a TXE6 stage control, depending on its position in the exchange, is from a few tens of milliseconds up to a maximum of 250 ms, and, from a calculation similar to the above, it would be able to handle about 6,000 calls an hour. This would be inadequate if the whole of a large exchange were to be controlled, but, as already explained, the unit for which the stage control is responsible represents only a part of the total switching capacity of the exchange. The number of calls to be handled by the unit is well within the limit stated, and many units may be operating simultaneously to meet the traffic demands of a large exchange.

In TXE3 the operation of interrogation, path choice, and signalling of instructions to markers (but not the actual marking operation) is performed one-at-a-time per exchange and takes 4 ms. The number of such operations per call depends on the type of call, while the distribution of different types of call depends on the traffic characteristics of the area

in which the exchange is located. Assuming, however, that an average of three operations is required per call, and that the occupancy of the one-at-a-time equipment is 0.4, the exchange will be capable of setting 120,000 calls per hour. This is probably a conservative estimate, but, if related to an average call-holding time of 2 minutes, it implies an exchange capacity of 4,000 Erlangs of subscribers' bothway traffic, equivalent, say, to a 10,000-line exchange with subscribers' average originated traffic of 0.2 Erlangs per line. This is adequate for TXE3 whose total capacity is limited somewhat below this figure by other factors, but is inadequate for TXE4 where exchanges of 40,000 lines and above are envisaged. The one-at-a-time operation in TXE4 (interrogation, path choice, and signalling to markers) will therefore be reduced, possibly to about three-quarters of a millisecond.

For TXE2 and TXE6 the effect of marking-equipment occupancy is included in the above discussion, but for TXE3 and TXE4 the marker occupancy must be taken separately. The large exchanges contain many switching sub-units, each with its own interrogating and marking equipment, and, although interrogation and path choice for a connexion involve the inspection of the many sub-units through which a path may be possible, marking involves only the two sub-units finally chosen for the connexion (see Fig. 5). Once the markers of these two sub-units have been instructed to act, which may occupy them for 30-40 ms, the one-at-a-time equipment is able to operate on behalf of other calls and can issue instructions to other markers while the first pair are still engaged. It is not possible, however, to interrogate sub-units in which marking is taking place, and the marking operations, therefore, produce artificial traffic-blocking by making all paths through the sub-units concerned look busy for the duration of the operations. For this reason, if a path-choice operation results in a "no-path" signal to the exchange common-control, the common-control initiates a second attempt after a short interval in case the reason was marker blocking.

MISCELLANEOUS PATH-CONTROL FUNCTIONS

Supervision

It has already been said that, once operated, the cross-point path is held from a supervisory circuit under control of the subscriber's loop. In TXE2 and TXE3 the supervisory circuits are relay-sets which are independent of the exchange common-control once the call is established. The supervisory element may appear in a link circuit, where it will be used for own-exchange calls and incoming calls (compare the final-selector supervisory element in a Strowger non-director exchange), or it may appear in an outgoing relay-set for outgoing calls. Link circuits are connected to the C-switch stages of these exchanges: outgoing-junction circuits are connected at the C stage in TXE2 and at the A stage (as for subscribers) in TXE3. In TXE3 a call from subscriber to outgoing junction must pass through a link circuit at the C stage, as shown in Fig. 5, but the link circuit in this instance will be a "through" link not containing a supervisory circuit. Since it is not possible for the outgoing-junction supervisory circuit to exercise direct H-wire control of more than the three cross-

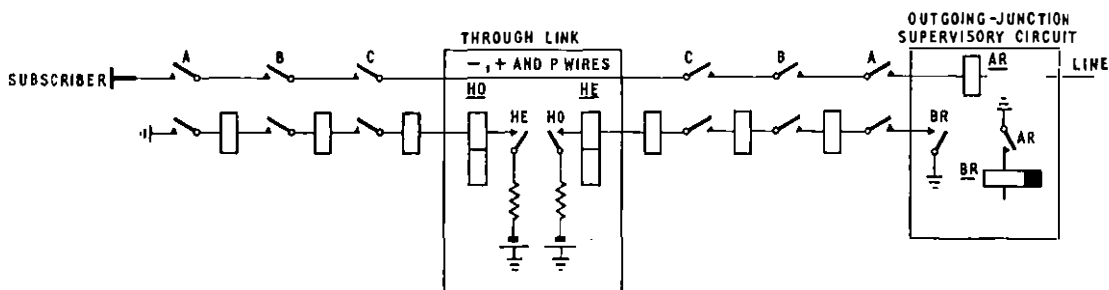


FIG. 7—Control of through-link circuit in TXE3

points connecting it to the through-link circuit, this link circuit must repeat the control to the remaining cross-points leading to the subscriber's termination. The principle is shown in Fig. 7.

In TXE4, the supervisory circuits are located similarly to TXE3, but they are not independent relay-sets. Instead they are grouped, and each group is controlled by a common electronic processing unit. Each supervisory circuit contains a relatively small number of simple slave relays. The processing unit scans its group of supervisory circuits regularly and in sequence, and, as it obtains access to each one, it notes the prevailing line conditions (e.g. loop, disconnection, called-subscriber answer) and issues instructions for the operation of the appropriate slave relays. The processing unit contains storage in respect of each supervisory circuit, as well as common storage and logic circuits, and receives instructions relating to a new call (e.g. identity of supervisory circuit, class-of-service of lines) from the exchange common-control via the marker highways at the same time as marking instructions for the call are issued to markers. Common processing has the advantages of space and cost saving, but attention must be paid to security requirements. Supervisory circuits are grouped to processors in such a way that any subscriber or other line may depend upon a number of processors: failure of any one will not seriously impair his service.

TXE6 is particularly for use in Strowger exchanges, and any given call may be wholly via TXE6 equipment or wholly via Strowger equipment, or may pass through both types of equipment. The supervisory circuit for such a call may be a normal Strowger one (e.g. part of a final selector) or a TXE6 one. In either case it may have to control both Strowger and TXE6 equipment simultaneously. TXE6 is a forward-holding system, the cross-points being held by an earth on the H-wire at the system input. A forward-holding supervisory circuit (Strowger or TXE6 register) will therefore have its P-wire connected to the system H-wire via the controlling-register access circuit. For a backward-holding supervisory circuit (e.g. a Strowger final selector) the P-wire earth is brought back to the input end of the system via the S-wire, and is there connected to the input H-wire via control relays in the controlling-register access circuit.

Path-Continuity Check

In the reed-electronic systems, each path is checked for continuity as soon as it is established, and, if the check indicates a fault condition, the control equipment initiates an automatic second attempt to set up the connexion. The equipment which provides the check facility must meet two requirements: first, it must have electrical access to the path at the instant the path is completed, and, second, it must be able to report the result of its test back to the controlling equipment before that equipment relinquishes control of the call. The controlling equipment can then initiate a second attempt based on the call details which it still has in hand. The dual requirement is met in all systems by the exchange registers, which are connected to both the physical path and the exchange control.

TXE6 is particularly well adapted to the check facility, since call-setting information is passed from stage to stage of a connexion along the speech path as previously described. It is arranged that a stage control signals back to the call-controlling register that it has received correct information. Failure to receive this confirmation causes the controlling register to re-attempt the call using alternative-stage outlets. In the remaining systems, the call-setting information is moved within the exchange control system and along separate highways, and the final speech path is not involved. The registers, therefore, have to rely on other means of checking path continuity. In some instances ready-made and checkable conditions appear on wires, e.g. P-wire earth, or negative-wire and positive-wire —50 volts and earth from supervisory

circuits; in others, there is no ready-made condition to check, and it may be necessary either to provide an artificial condition solely for this purpose or to omit the check on certain types of connexion. The latter course is not so unsatisfactory as it may sound, since a given part of the switching network will be used for various types of connexion, and will not remain long undiscovered if faulty.

In all systems, discovery of a faulty path is followed by print-out of path information which will assist maintenance staff to locate the fault.

Call and Path Trace

It is often necessary to trace a connexion from a given network terminal, such as a subscriber's line or a junction, to find either the terminal at the other end of the connexion (call trace) or the complete path of the connexion through the switches (path trace). In the Strowger system there is no real separation here since call trace is achieved by tracing a connexion through successive switching stages by inspecting the positions of the mechanisms, thus automatically revealing the path of connexion. In the reed-electronic systems, physical inspection of the switches would be of little help and electrical techniques are used.

In TXE2 a signal is applied via a test point on the A-switch to the P-wire of the line circuit at the known end of the connexion. The signal passes through the switch network and causes a neon lamp to flash on the associated supervisory relay-set. The call can equally well be traced in the reverse direction and, with the aid of simple plug-in equipment, through the intermediate switching stages. This method is simple and reliable, and the physical activity involved in tracing a call is not great in this size of exchange.

In the large exchanges, the physical activity would be less convenient. A wholly automatic technique is preferable and can be provided at moderate cost in relation to the overall cost of an exchange. TXE3 makes use of the marker leads for call-trace purposes, the process being illustrated in principle in Fig. 8. The equipment number of the known end of the connexion is fed into the exchange common-control, and results in the establishment of a special path through the ordinary network to link the call-trace control circuit via a marker to the P-wire of the connexion to be traced. A pulse is applied to the P-wire and finds its way back to the link circuit engaged in the call, operating a relay in the link circuit. This relay connects a special voltage to the H-wires on either side of the link circuit, resulting in a shift of potential on the H-wires of the connexion being traced. It also operates relays to give the call-trace control circuit access to all marking wires of the two sub-units to which the link-circuit is connected, and the control circuit is able to identify the numbers of the switch inlets and outlets on which the potential shift has occurred. These enable the control circuit to display on digital indicators the equipment numbers of the two ends of the connexion: one is the known end, the other the required end. It is inherently possible in this process to obtain full details of the connexion path, and either call trace or path trace may be selected by appropriate key operation on the control circuit.

TXE6 uses a semi-automatic means of call trace. In the case of forward trace an increased voltage is applied to the known inlet H-wire. This voltage continues to hold the cross-point relays previously operated and provides a unique detectable condition. The mark wires connected to the output sides of the A-switches are scanned by rotating a 20-position rotary switch, the wiper of which is connected to a detector circuit. Cross-points in the free position have no voltage drop across them and are undetected. When the switch reaches the engaged cross-point the voltage drop across the coil is detected and the "forward-call-trace" lamp extinguished. The position of the switch indicates the A-switch cross-point operated. Similarly the B-switch mark leads are scanned by a 10-position switch and the B-switch cross-point is located. For a backward trace

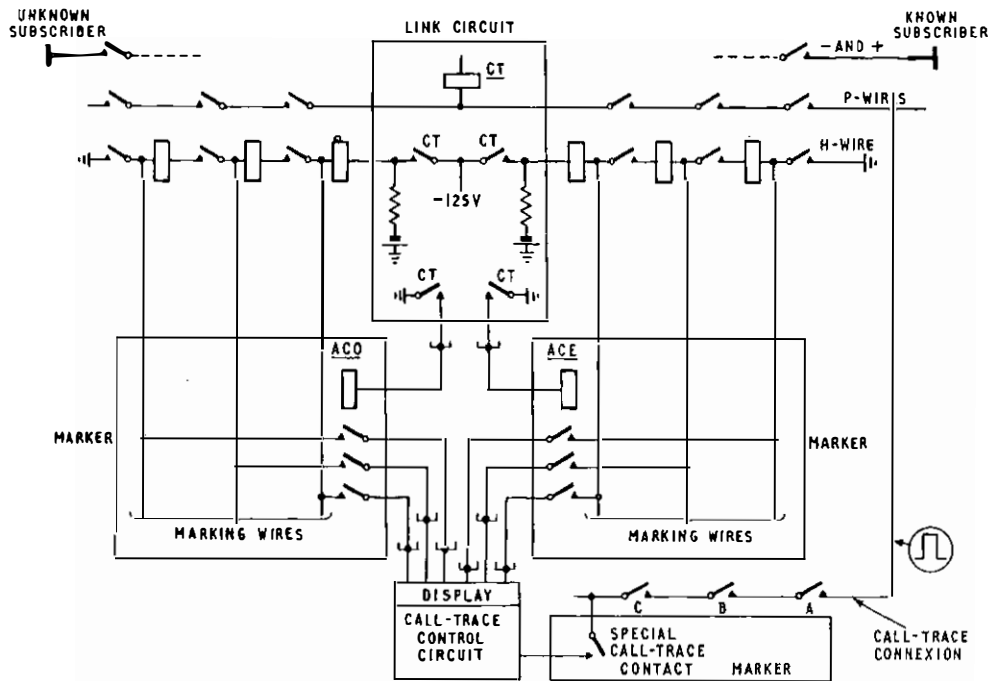


FIG. 8—Call-trace operation in TXE3

a voltage detector is connected to the known outlet H-wire and an 8-position switch is rotated, connecting increased voltage to all inlets of each switch in turn. When the detector extinguishes the lamp, the switch position indicates the required A-switch number. With the first switch restored, a second 12-position switch is rotated, and this now connects increased voltage in turn to all like-numbered inlets of each A-switch. When the lamp is again extinguished the switch shows the required inlet number.

POSSIBLE DEVELOPMENTS

In all four systems dealt with in this article the switched connexions make use of the four wires referred to earlier, viz: negative and positive wires, P-wire and H-wire. Most Strowger exchanges use only three wires for local-exchange work and this, fundamentally, is all that is required. In at least some systems, if metering signals were not required on the P-wire, the functions of the H-wire and P-wire could be combined. This would lead to substantial savings: a quarter of the cross-point reed-relay contact-units, and a corresponding quantity of wiring and wire terminations. It is difficult to eliminate the metering requirement unless some entirely different metering scheme is employed: at present, conventional meters are used in all systems.

The means of providing an alternative scheme may be linked with the possible solution to another problem. Interrogation of the H-wires of the larger exchanges involves the use of a very large number of pulse-plus-bias gates permanently attached to the switching network. Although these are about as cheap as such a device could be, they are, nevertheless, more expensive than is desired. An alternative arrangement, bearing in mind the continually decreasing cost of electronic

storage, would be physically to detach the means of interrogation from the switching network: that is, to represent the state of the network in a completely separate store, which would be up-dated as connexions were set-up or released within the real network. Access to this store would then be obtained for information as to the state of the network whenever it was required to set a new connexion. There are obvious dangers in such an arrangement—what if the store gets out of step with the network?—but if these sort of problems are solved it could be a better way of doing the job and would fit in well with newer ideas on exchange control.

Suppose this technique were introduced and were used in such an exchange as TXE4 which had its call-supervisory circuits controlled by common electronic processors. The supervisory processors and the interrogation store would between them contain the basic information on which a new call-charging scheme could be based, i.e. details of engaged switch paths (which could indicate the identities of subscribers associated with particular supervisory circuits) and details of the type and duration of a call. Thus, the introduction of a new interrogation technique could not only cheapen interrogation itself, but might make possible a cheaper 3-wire switch network.

CONCLUSIONS

A recognizable set of speech-path control problems requires solution in any telephone exchange system. In a reed-electronic system, the optimum solution depends on the size of the system being considered and the speed at which control equipment must work. Future refinements of technique may bring further economies.

Intermediate-Frequency Switching Systems for Microwave Radio-Relay Links

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The high concentrations of traffic that can result from the use of microwave radio-relay links make reliability of first importance. Protection channels play a vital role in enabling a reliable service to be achieved, and the problems of switching traffic between working channels and protection channels are discussed. Intermediate-frequency switching systems will be used with most major microwave radio-relay links in the British Post Office network. This article describes the principles of such a switching system, its advantages over baseband switching systems, and the basic elements of the equipment.

INTRODUCTION

Inter-city microwave radio-relay systems now form an integral part of the United Kingdom trunk telecommunication network. The traffic capacity of such a radio-relay system is high and, typically, provides for many hundreds of telephone or data circuits or an internationally-agreed colour-television signal. The Administrative Radio Conference has agreed on radio-frequency bands for fixed point-to-point systems; those available to the British Post Office for civil trunk communication purposes are the 2 GHz and 4 GHz bands, two bands in the 6 GHz region, commonly called the lower 6 GHz and upper 6 GHz bands, and the 11 GHz band. The International Radio Consultative Committee (C.C.I.R.) has recommended frequency-channelling plans for these bands. Each band is sub-divided into a number of radio channels centred on specified radio frequencies; these radio channels are generally referred to as broadband channels, to signify the wide baseband* that can be accommodated, and six such broadband channels in each direction are available in both the 2 GHz and 4 GHz bands. In the lower 6 GHz band eight broadband channels, using 30 MHz spacing, are available in each direction, whilst the upper 6 GHz band can accommodate 16 broadband channels, using 20 MHz spacing, in each direction. The precise division of the 11 GHz band has yet to be finalized.

The baseband capacity at present available per radio channel in the 2 GHz band is 960 telephone channels multiplexed on a frequency-division basis representing a baseband width of 4 MHz. Both the 4 GHz and lower 6 GHz bands can accommodate 1,800 frequency-division multiplex (f.d.m.) telephone channels (representing a baseband width of 8 MHz), and the upper 6 GHz band has a capacity of 960 f.d.m. telephone channels per radio channel.

From the foregoing it will be realized that inter-city microwave radio-relay systems can operate with very high concentrations of traffic, and reliability is of vital importance. To meet this demand for reliability it has long been the practice to allocate certain broadband channels as protection channels. That is to say, under normal conditions the protection channel does not carry traffic but is available as an alternative circuit should one of the main channels become unserviceable.

The transfer of traffic between main and protection

channels is carried out automatically, and the method that will be employed on the majority of main-line inter-city routes in the United Kingdom uses intermediate-frequency (i.f.) switching. This article describes the basic principles of this system and its advantages over other earlier methods of switching.

TYPICAL MICROWAVE RADIO-RELAY LINK

Before discussing i.f. switching it may be helpful to review the make up of a microwave link.

The essential elements are shown in Fig. 1. For simplicity, only one repeater station is shown, but links may have several, usually spaced at about 30-mile intervals.

At the transmit terminal the baseband signal is adjusted in level as necessary, pre-emphasized and then arranged to frequency modulate a 70 MHz oscillator, this frequency being the i.f. recommended by the C.C.I.R.

The frequency modulated (f.m.) signal in the spectral range 55–85 MHz is then applied to a mixer together with a microwave signal from an oscillator. The output from the mixer will contain upper and lower sidebands, each being a complete frequency-modulated signal. Thus, each sideband contains all the essential information, but only one is selected by a band-pass microwave filter. The microwave signal is then amplified by a travelling-wave tube and applied via a feeder system to an aerial, which is either a parabolic dish or a horn.

At the receive terminal the microwave signal beats with a local-oscillator signal to produce an i.f. signal that is amplified to a fixed level and fed to a limiter to remove any residual amplitude-modulation components from the f.m. signal. Frequency-to-voltage conversion is then carried out in a discriminator and, after passing through a de-emphasis network, the original baseband signal is retrieved.

A repeater is essentially similar to the microwave and i.f. portions of a receiver and transmitter connected back to back at the i.f. point.

The failure of any part of the equipment in the link as described above would result in the loss of the traffic circuits.

EARLY PROTECTION ARRANGEMENTS

In one of the first microwave links¹ each item of equipment was duplicated, using the same frequencies, as was the usual practice in coaxial-cable systems. At each station a mechanical waveguide switch was installed in the aerial-feeder system and, if the main equipment should fail at any one station, the switches at that station would connect the duplicate stand-by

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* The term baseband refers to the band of frequencies transmitted by the radio system between its input and output terminals.

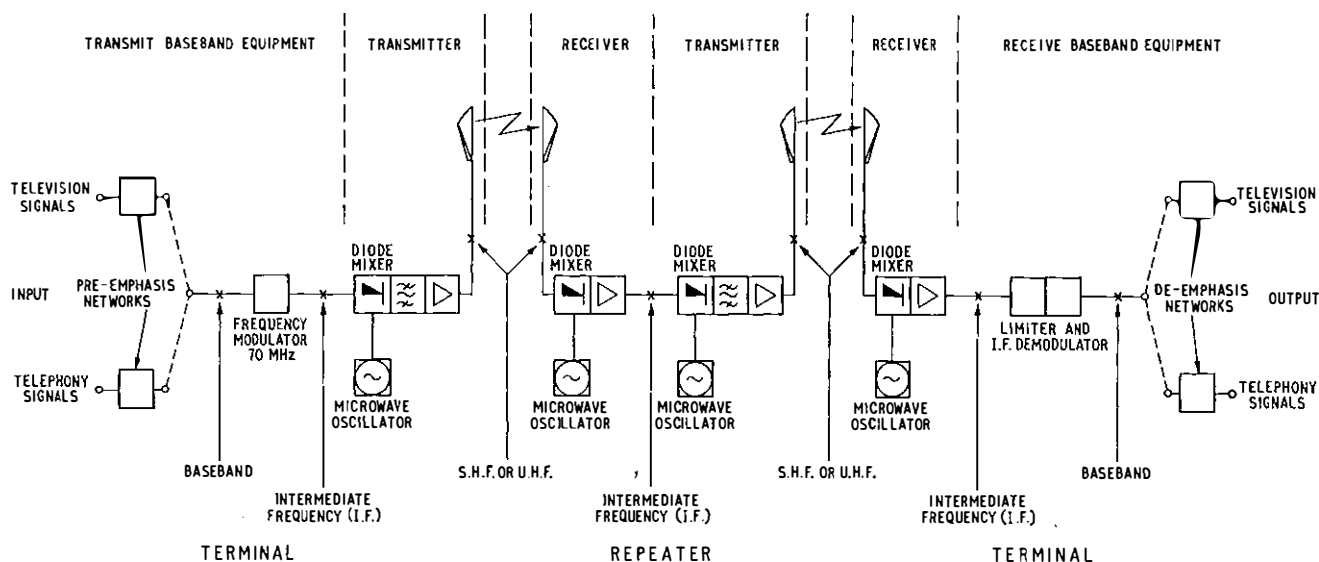


FIG. 1—Typical microwave link, showing one broadband channel only

equipment to the aerial system in its place. In practice, this system had certain disadvantages: the switches were relatively slow to operate, taking several seconds to effect a change-over, and, since the protection equipment was an exact replica of the main equipment and had to be switched at a point of high power level, crosstalk between the main and stand-by equipment was difficult to eliminate. A more serious disadvantage was that it was not possible to be sure that the protection equipment, when switched into circuit, would be in full working order.

Protection Channels

The disadvantages described above can be overcome if, instead of duplicating each item of equipment, a complete spare channel from end to end is provided using another frequency. The waveguide feeder switches at each station can then be dispensed with and the protection channel can be permanently connected to the aerials. If a failure of the main circuit occurs at the terminal stations the baseband signal can be transferred to the protection channel, using, for example, an electromechanical relay that can be made to operate more rapidly than the earlier waveguide switch.

This arrangement thus offers the following advantages.

(a) Maintenance is facilitated, since a working channel can be replaced by the protection channel and tested without interrupting traffic.

(b) Continuous automatic monitoring of the protection channel can be arranged, thus helping to ensure that it is ready for service when required.

(c) The protection channel can be made available for carrying traffic on an occasional basis and for television outside broadcasts, etc., provided that its primary protection function is retained.

Until about 1959, each working channel had its own exclusive protection channel, since most routes had not developed sufficiently to require more than one working channel. As the network developed, however, this practice was clearly uneconomical, and protection channels were shared between several working channels. Experience to date shows that on major routes with valve-type equipment a satisfactory degree of reliability is obtained with one protection channel for up to three working channels. For convenience, the protection channels are normally located in the same frequency band as the main channels.

Fig. 2 shows two baseband-switching arrangements commonly employed. The arrangement in Fig. 2(a) can be used if only one main channel exists, and has the advantage

that switching need occur only at the receive-end terminal. Fig. 2(b) shows the arrangement used if two or more main channels are to be protected. Note that switching actions must now occur at both terminal stations. The radio link between these two terminals is referred to as a switching section.

CONDITIONS REQUIRING SWITCHING ACTION

One misconception about microwave radio-relay links is that protection channels and automatic switching systems are needed because radio links suffer from fading. Protection channels are not provided to guard against fading. Indeed, since the protection channels are usually located in the same frequency band as the working channels, it is rare for a variation of propagation conditions to occur that can cause one channel to fade but leave other channels unaffected. Protection against severe fading can only be secured by careful choice of routes, sites, etc., and the use of diversity reception.

It is arranged that switching shall occur

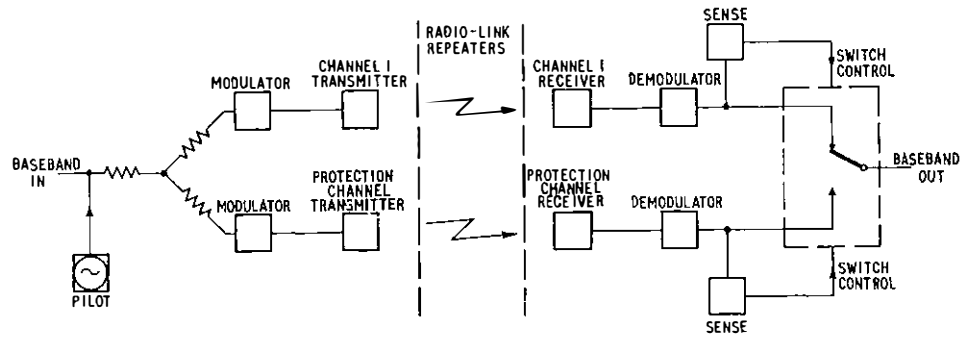
- (a) if the circuit is interrupted due to equipment failure, or
- (b) if the noise in the baseband should rise to a level that would seriously degrade the transmission performance of the circuit.

Increased noise may be caused, for example, by a decrease in the output power of a travelling-wave valve, so that the received signal level at the next station falls. The automatic-gain-control action of the radio receiver will restore the signal level to normal, but will further amplify the thermal-noise voltage developed across the resistive component of the input impedance, thereby increasing the noise level in subsequent parts of the system.

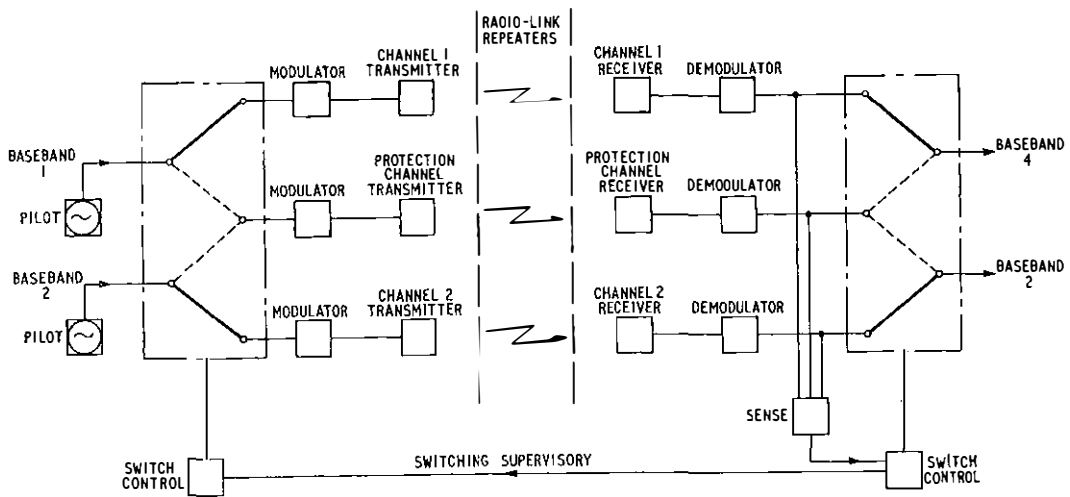
Switching to overcome this condition is initiated by monitoring the noise level at the baseband output in a narrow noise-measuring band which is usually located above the highest working baseband frequency, and experience has shown that a change-over is desirable when the noise rises to a level of about 10,000 pW (— 50 dBm0) in any telephone channel.

Catastrophic equipment failure, which would result in a complete loss of traffic, is detected by monitoring a continuity pilot, which is inserted, together with the baseband signal, at the input to the system. It is convenient to locate this continuity pilot in the centre of the noise-measuring channel, since this simplifies the detector filtering arrangements.

It should be noted that even catastrophic equipment failures are not necessarily instantaneous but may take an appreciable



(a) One Working and One Protection Channel (1 + 1 System)



(b) More than One Working Channel (2 + 1 system)

FIG. 2—Principle of early systems of baseband switching

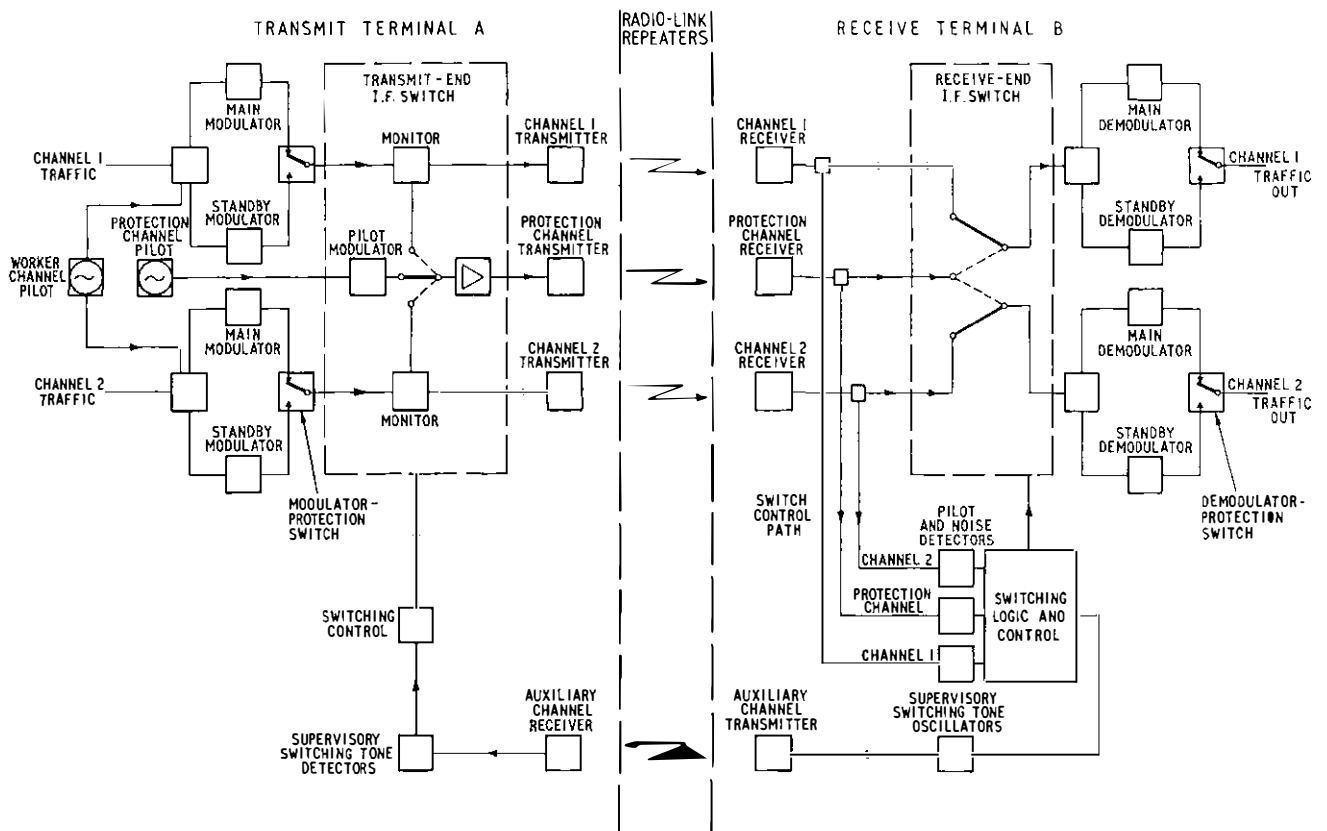


FIG. 3—Principle of i.f. switching system (2 + 1 system)

fraction of a second, especially with thermionic-valve equipment. Thus, in some instances the noise-detector circuits will operate within a few milliseconds of the onset of a fault, and a change-over to the protection channel may be made before the traffic is lost.

For radio systems with a capacity of 1,800 telephone channels per radio-frequency carrier, pilot frequencies of 9.023 MHz for working channels, and 8.5 MHz for protection channels, are used. For 960 telephone channels per radio-frequency carrier the working pilot is usually 8.5 MHz and the protection-pilot frequency 8.0 MHz. If television signals, of either 405-line or 625-line standard, are transmitted instead of broadband telephony, the same pilot frequencies are used.

A fault causing loss of pilot, indicating a break in the continuity of the traffic path, is more serious than one causing degradation of the signal-to-noise ratio. It is, therefore, arranged that failures due to loss of pilot shall take precedence over high-noise level. If a protection channel is carrying traffic due to the fact that one normal working channel is noisy, and, subsequently, another working channel has a pilot failure, then the protection channel is made available by returning the traffic on it to the noisy working channel in order that the traffic from the working channel registering a pilot failure may be transferred.

I.F. SWITCHING SYSTEM

I.F. switching systems are now being brought into use on most major inter-city links. Fig. 3 shows the principle of such a system. For simplicity, only two working channels and one protection channel are shown but the system described can operate with more channels—typically up to six working and two protection channels, a so-called 6 + 2 system.

At the transmit end, terminal A, the traffic baseband is applied, together with a working-channel continuity pilot, to a pair of modulators (the reason for this is discussed later). The frequency-modulated i.f. output from one modulator is selected by a modulator-protection switch and routed via a transmit i.f. switch to a working channel. At the receive-end, terminal B, the i.f. output from the receivers is split into two paths: a traffic path and a switch-control path. The traffic path is routed through a receive i.f. switching rack to a pair of demodulators which recover the baseband signal. The output from one demodulator is then selected.

Also connected between the transmit-end A and receive-end B i.f. switches is a protection channel which is not carrying main traffic information and, hence, no traffic modulators or demodulators are associated with the channel. A continuity pilot, of different frequency to the working-channel continuity pilot, is applied to the protection channel by a pilot modulator. At the receive-end B terminal the protection channel is also split into two paths, one for switching control and one to the receive i.f. switch.

The control paths at receive terminal B monitor the working and protection channels. If a working channel should fail and the protection channel is satisfactory, then control equipment at receive terminal B sends switching instructions, via a supervisory circuit, back to the transmit terminal A. On receipt of the switching instructions the transmit i.f. switch connects the input terminals of the failed working channel in parallel with the input terminals of the protection channel, i.e. the i.f. output from the working modulator is fed to both working and protection channels. This paralleling action removes the protection continuity pilot from the protection channel and replaces it with the working-channel traffic-continuity pilot. The receive-end i.f. switch monitors the protection channel, and, when the working pilot is received in place of the protection pilot, switches the demodulators from the failed working channel to the protection channel. This is termed end-to-end i.f. switching action.

It should be noted that the traffic is not removed from

the failed working channel, so that, at the receive terminal, the monitoring process continues and, when the channel again becomes serviceable, the receive i.f. switch can restore to normal. Thus, the traffic path is disconnected only during the switching action of the receive-end i.f. switch.

Facilities are included for manual change-over for maintenance or other purposes, and it is also possible to disconnect a protection or working channel from the switching system entirely. This can be done either manually or automatically if, for example, a protection channel becomes faulty itself and cannot be used to protect working channels. This is called the lockout facility.

Modulator and Demodulator Protection

The process just described caters for failure of the working channel at any point between the transmit-end i.f. switch and the receive-end i.f. switch, i.e. failure at a repeater station or of the radio transmitter or receiver at a terminal station. If, however, a modulator were to fail, the end-to-end i.f. switching could not restore the traffic. The modulators, therefore, must be protected separately, and two modulators per working channel are used, a local switch selecting the output from only one modulator at any one time. It is necessary to switch the output of modulators rather than to combine their outputs, since no suitable combiners are available for f.m. signals of the type involved. The modulator-protection switch is another i.f. switching point employing similar circuit arrangements to the main end-to-end i.f. switches and is controlled by the same working pilot as the end-to-end i.f. switch.

Similarly, two demodulators are allocated to each working channel, and the output from one is selected by a demodulator-protection switch. The output from the demodulators is the baseband signal, so that a different circuit is necessary from that used for the modulator-protection switch, and, usually, a high-speed electromechanical relay is used, again controlled by the working pilot.

Thus, in the complete i.f. switching system there are three switching functions:

- (i) end-to-end i.f. switching,
- (ii) modulator-protection switching, and
- (iii) demodulator-protection switching.

The end-to-end i.f. and demodulator-protection switching functions are designed to operate only after first checking that by so doing the traffic path will be restored.

For example, consider a modulator failure. This will remove the pilot from the entire link, and both the end-to-end i.f. switching and the demodulator-protection switch will attempt to change over. But when the protection radio channel and the protection demodulator are checked the pilot will be found to be absent. Hence, no change-over by these latter two switches will occur, but a change-over to the protection modulator will restore the traffic path.

Similarly, if the working radio channel fails, the demodulator switch, although registering loss of pilot, will not change over, since the pilot will be absent from the protection demodulator also.

Switching Sections in Tandem

One major advantage of i.f. switching compared with the earlier methods of baseband switching can be realized when, in order to provide a broadband channel between two points, two or more switching sections are connected in tandem as in Fig. 4, where two i.f. switching sections, A-B and B-C are connected so as to provide a broadband telephony channel between terminals A and C.

Distortion arising from modulation and demodulation is an important factor in the performance of f.m. radio systems, and a high degree of linearity is needed if intermodulation distortion is to be kept down to acceptable proportions. The

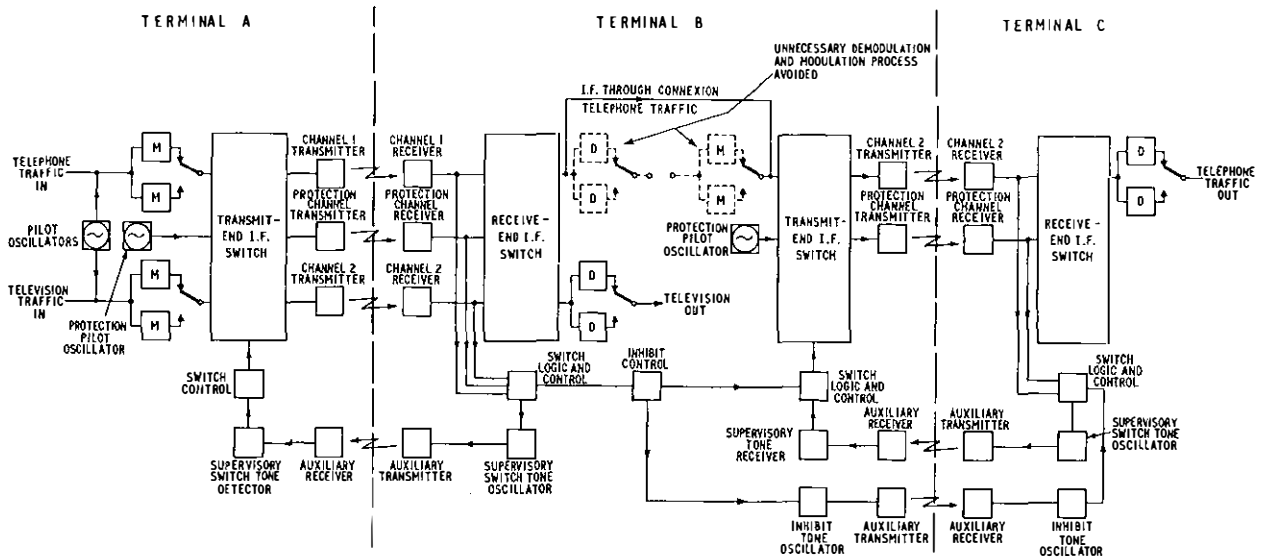


Fig. 4—Two radio links in tandem, each using i.f. switching

modulation and demodulation processes can contribute as much as a quarter of the total noise per telephone channel and cause the major portion of non-linearity distortion of television waveforms. For this reason, repeater stations on microwave radio-relay systems are of the non-demodulating type.

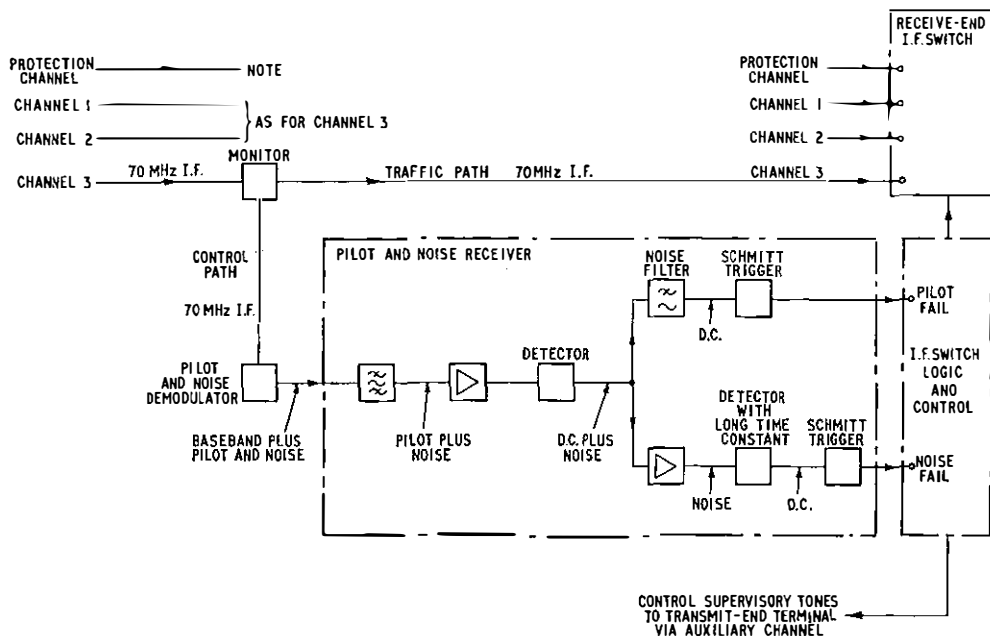
I.F. switching enables terminal B to be operated as a non-demodulating repeater, since the i.f. output from the receive-end i.f. switch on section A-B may be taken directly to the i.f. input to the transmit-end i.f. switch on section B-C. The through connexion at i.f. does not interfere with the independence of the two switching sections. Failure of channel 1 on switching section B-C will only cause a change-over to the protection channel on the section B-C, leaving channel 1 on section A-B in its normal condition, and vice-versa. This is important, as it is clearly desirable to leave the protection channel in section A-B free to protect the other working channels on this switching section.

By referring to Fig. 2, it can be seen that if two baseband switching sections are connected in tandem this condition cannot be realized, i.e. the signal would be unnecessarily demodulated and re-modulated in order to maintain the independence of the two switching sections.

Detecting Pilot Failure or Excessive Noise

Fig. 5 shows the pilot-failure and noise-detection system. At the receive-end terminal each channel is split into a traffic path and control path. The i.f. signals on the control path are demodulated, and the resultant baseband and pilot are fed to a pilot-receiver panel.

A narrow band-pass filter limits the signal to a noise band centred on the pilot frequency. The output from this filter comprises the pilot frequency in the centre of the band together with a certain amount of noise distributed through this band. Regarding the pilot frequency as a carrier, the signal is detected to produce a d.c. output proportional to the



Note: The protection control path has two pilot receivers to cater for working-channel and protection-channel pilot frequencies

FIG. 5—Pilot-failure and noise detection

pilot level plus higher-frequency noise components. This output is split into two paths. In order to detect the pilot the higher-frequency noise components are removed by a low-pass filter, and a d.c. voltage proportional to the pilot level is used to control a Schmitt-trigger circuit. The output of this trigger circuit operates the receive-end control circuits for the i.f. switching and operates a local alarm system to indicate pilot failure.

To detect high noise levels the noise components are separated from the d.c., amplified, rectified and smoothed to give a second d.c. component proportional to the noise level in the radio channel. This is used to control a second Schmitt-trigger circuit. The output of this circuit operates the receive-end i.f. switch for high-noise conditions and also operates a local excess-noise alarm.

For the stand-by-channel pilot and noise detector the normal stand-by pilot frequency is different from the working-channel pilot frequency, but when a change-over to the protection channel is initiated the working pilot frequency replaces the protection pilot. Thus, two pilot-receive filter circuits are required and are operated in parallel, allowing pilots of either frequency to be detected. A separate noise-channel measuring circuit, permanently tuned to the band centred on the working pilot frequency is also incorporated.

If pilots of both working and protection frequencies are detected simultaneously, which would indicate a false operation of the switching system, then no change-over to the protection channel occurs and an appropriate alarm is given.

For operation of the modulator and demodulator protection switching, only pilot-level variation is monitored, since noise will be contributed mainly in the radio equipment and is thus used to operate the end-to-end i.f. switching only.

For the demodulator switch, the pilot signal is monitored after the discriminator and the pilot simply filtered off. To protect the modulator, however, it is first necessary to monitor the f.m. i.f. signal and use a separate discriminator to restore the signal to the baseband frequency range. The pilot-level detectors are similar to those described above.

BASIC I.F. SOLID-STATE SWITCH

Fig. 6 shows the basic circuit diagram of the i.f. switch, originally developed for diversity-switching purposes.² For

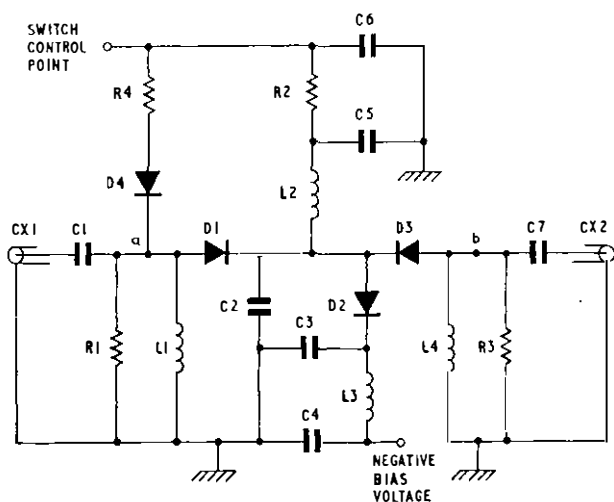


FIG. 6—Basic i.f. switch

the “on” condition a negative voltage is applied to the switch-control point, and diodes D1 and D3 conduct, the current paths being resistor R2, inductor L2, diode D1, inductor L1 and resistor R1, inductor L2, diode D3 and inductor L4. Resistor R2 controls the diode currents, and inductors L1, L2 and L4 are d.c. paths only and have a high impedance at 70 MHz. The negative voltage which causes diodes D1 and

D3 to conduct, together with the negative bias applied via inductor L3, cuts off diode D2. Inductor L3 also offers a high impedance at 70 MHz whilst a low-impedance signal path from socket CX1 via diodes D1 and D3 exists.

The values of resistors R1 and R3 and capacitor C2 are so chosen that the input impedance at point CX1 is 75 ohms when point CX2 is terminated in 75 ohms. Capacitors C3, C4, C5 and C6 provide decoupling at 70 MHz, whilst capacitors C1 and C7 are for d.c.-blocking purposes only.

For the “off” condition of the switch a positive voltage is applied to the switch-control point. Diodes D1 and D3 are now non-conducting and offer a high impedance in the signal path. The same positive voltage causes D2 to conduct, and the low forward impedance of diode D2 in series with capacitor C3 across the signal path highly attenuates an i.f. signal applied to socket CX1.

The off condition causes a high impedance to be presented at sockets CX1 and CX2 and, in order to maintain the input impedance at 75 ohms, it is necessary to include diode D4 at point a which, when the above positive voltage is applied to the switch control point, conducts and shunts resistor R4 across the input. Resistor R4 is chosen so that the combination of resistor R4, diode D4 and resistor R1 present 75 ohms at socket CX1.

A similar arrangement connected to point b will terminate the output in 75 ohms also.

The insertion loss of the switch in the on condition is dependent, among other factors, on the forward resistance of diodes D1 and D3, and the insertion loss in the off condition is reduced by the leakage capacitance across diodes D1 and D3 when they are non-conducting. A gold-bonded diode which has a low forward voltage-drop with a high-impedance reverse characteristics is, therefore, generally used for all diodes in the circuit, together with careful component layout to avoid stray capacitance effects.

The insertion loss in the on condition is approximately 2 dB and in the off condition is approximately 80 dB.

By suitable arrangements of a number of the above basic units the transmit-end and receive-end switching function is carried out as described in the following section. The basic circuit is also used for the modulator-protection switching.

6 + 2 Diode Switching Arrangement

Using the basic diode switch as a building block, a network for switching up to six working channels to either of two protection channels may now be considered.

Fig. 7 shows the principle of transmit and receive ends of an i.f. switching section with diode switching points shown as mechanical switches. At the transmit end it is necessary to parallel, as required, any one working channel with either protection channel X or Y and at the receive end to switch from the appropriate working channel to the i.f. signal from receivers X or Y, as required. It must also be remembered that occasional access to protection channels X or Y, when they are not in use, is catered for, but this occasional traffic must be automatically removed when the protection channel is taken into use to replace a failed main channel. Thus, if the traffic channel 2 is required to be routed via protection channel X, then the diode switch in the switching unit at the transmit end associated with circuit 2 between coaxial sockets CX1 and CX2 must be switched on and any occasional traffic on protection channel X must be removed by switching off the diode switch between points CX4 and CX8 in the protection-channel switching units.

At the receive end the normal traffic path though the switching unit is from socket CX10 to socket CX1. If protection channel X is used, then the switch must go to socket CX2 or to socket CX3 for protection channel Y.

This action must coincide with disconnection of the occasional traffic path CX4 to socket CX8 for protection channel X or socket CX5 to socket CX7 for protection channel Y.

Since the switching requirements are the same for each

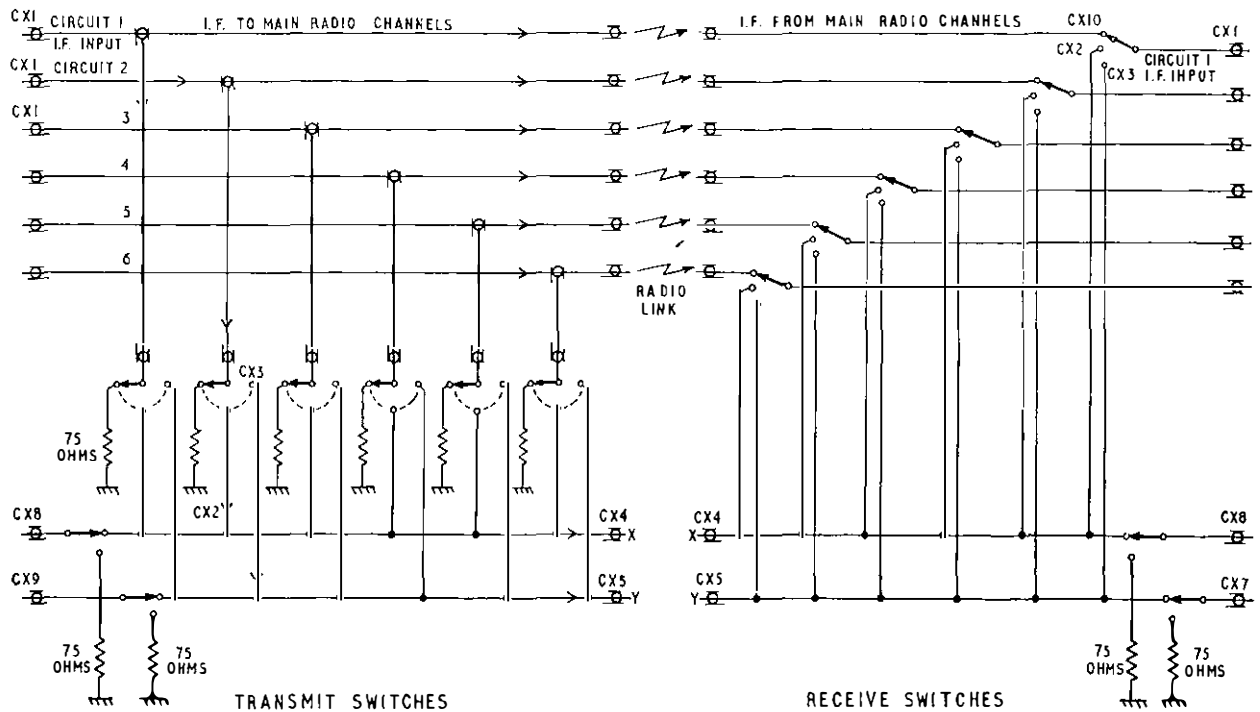


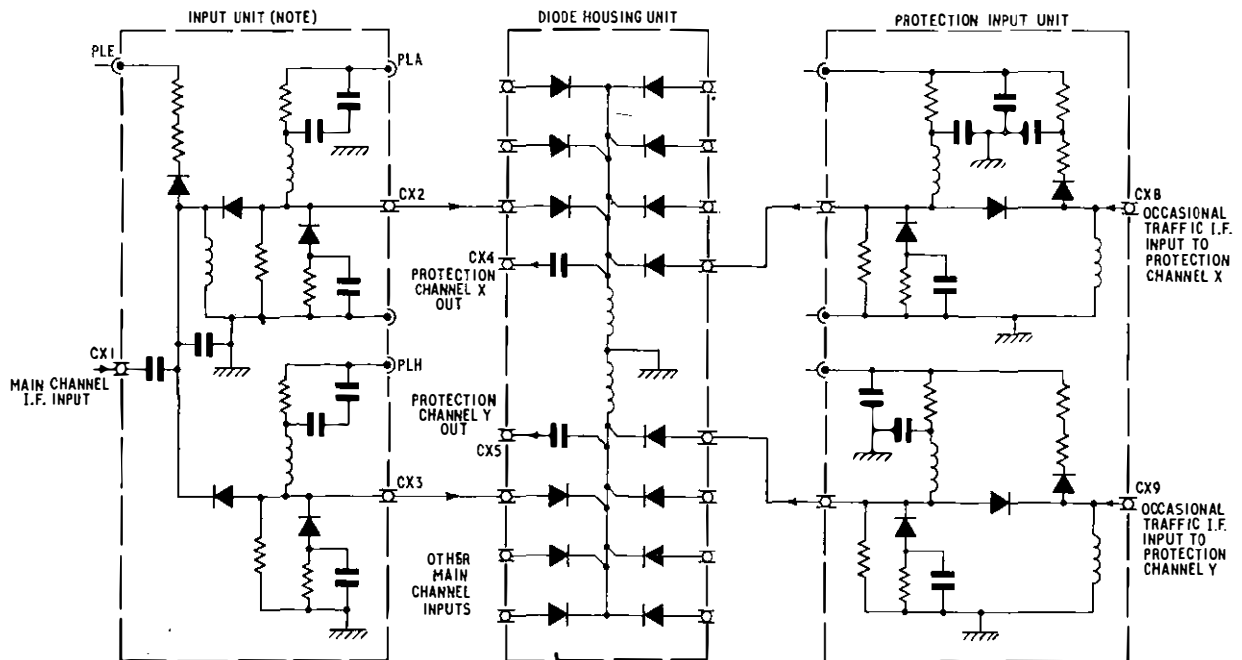
FIG. 7—Principle of 6 + 2 i.f. switching

main channel, it is possible to effect some reduction in the number of components required by making parts of the basic diode switch common to more than one network.

Referring back to Fig. 6, more than one basic diode switch may be connected to socket CX1, the connexion being made at point a. The biasing components will be common to the extra switches if added. Only one i.f. path must be available at any one time, i.e. only one switch in the on condition, the remaining switches and the 75-ohm termination being off. If all the switches are off then the termination must be on.

Similarly, more than one basic diode switch can be connected to a common output at point b (Fig. 6), provided that only one switch or a termination is on at any one time.

At the transmit terminal it is convenient to connect two diode switches to a common input for each working channel, so that one switch will connect the i.f. signal to protection channel X and the other to protection channel Y as required. It is convenient to consider the switch bisected into two units, which will be referred to here as the input unit and the diode unit; Fig. 8 shows the principle involved. Each main channel has an input unit, and the outputs CX2 and CX3, when connected to the associated diode in the diode unit, form two diode switches. Under normal conditions -6 volts is applied to points PLA and PLH, holding the switches off, and -6 volts applied to point PLE terminates the input in 75 ohms. If protection channel X is required to carry the traffic for the



Note: one input unit per working broadband channel

FIG. 8—Transmit-end switch arrangement

particular main channel being considered, then the i.f. signal must be routed from socket CX1 on the input unit to socket CX4 on the diode housing-unit via socket CX2. To achieve this the voltage at points PLA and PLE is changed to +6 volts, removing the 75-ohm termination and switching on the required switch, point PLH remaining at -6 volts.

Also connected to the diode housing-unit is an input unit for occasional traffic on protection channels X or Y. This input unit is basically two diode switches, one for channel X and one for channel Y. The control voltages for switching on or off the switch and the termination are the same in principle as for the main-channel switch. The switching-control logic is so arranged that if a main channel is to be changed over to protection channel X then the protection channel X switch will be off and terminated in 75 ohms and similarly for protection channel Y. If channels X and Y are free then the control voltage of +6 volts on each switch will allow the switch to be on and provide a through path for occasional traffic on the protection channel.

At the receive terminal a similar technique is used. At this terminal it is convenient to connect three diode switches to a common i.f. output. Again, for convenience, the basic switch circuit is broken down into an input unit and a diode unit. One input unit is allocated to each main channel. The input unit contains three switching functions: one diode switch routes the i.f. signal from the main receiver from its input socket CX10 to the common output socket CX1; the two other switches in the input unit, formed when used with the diode housing-unit, are for routing the i.f. output from the receivers on channels X or Y to socket CX1 as necessary.

A complete equipment is shown in Fig. 9.

END-TO-END SIGNALLING SYSTEM

Voice-frequency (v.f.) tones are used to signal the switching instructions between terminals. These tones are transmitted over an audio channel (0.3-3.4 kHz) provided by an auxiliary system, which may be a 4-wire land line, a v.h.f. radio link, a s.h.f. radio link or a sub-baseband on the main radio carriers operating in the required direction. Nowadays a s.h.f. narrow-band radio link using the same aerials and feeders as the main channels is normally used and other audio channels are added in f.d.m. to carry speaker circuits, etc. To ensure that the switching tones are reliably transmitted it is usual to duplicate the narrow-band radio link, i.e. there is a main and protection auxiliary system.

For a 6 + 2 system 10 v.f. tones are used for signalling between the switching terminals. Five tones are associated with the first-choice protection channel and five with the second choice. With the system normal, i.e. with all main channels satisfactory and both protection channels free, two tones, designated guard 1 and guard 2, are transmitted over the audio channel.

Four of the remaining tones associated with protection channel X are used in pairs, giving six possible combinations. Each combination represents one of the six main channels, and, when transmitted, indicates that the faulty channel must be switched to protection channel X. Similarly, four tones associated with protection channel Y indicate which main channel must be switched to protection channel Y.

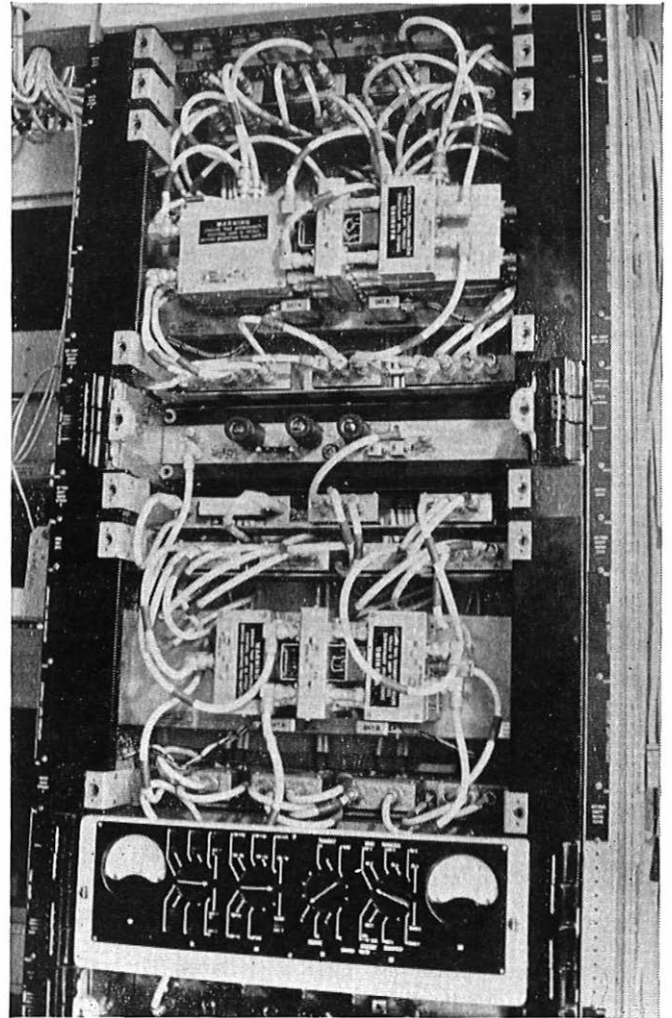
At the transmit terminal the tones are detected and used to operate the transmit i.f.-switch control circuits.

SWITCHING TIMES

It is now necessary to consider the time taken for the operation of the switching system and the effect on the continuity of the baseband traffic.

The following list shows the sequence of events during an i.f. switching action and the approximate time involved for each stage.

- (i) Excessive noise or pilot failure occurs: response



The equipment shown is for both a transmit and a receive (6 + 2) two-direction system

FIG. 9—I.F. switching equipment

time of the appropriate detector circuit at the receive terminal	1 ms
(ii) Logic time of receive i.f. switch: time taken to ascertain which protection channel to use and to assemble the appropriate v.f. signalling tones	6 ms
(iii) Time delay in transmitting v.f. signalling tones between receive and transmit terminals	1 ms
(iv) Response time of v.f. tone receivers and logic time of transmit i.f. switch	12 ms
(v) Time taken by transmit i.f. switch to parallel main and protection channels	5 μ s
(vi) Response time of protection-channel pilot-detector at the receive terminal to check that main-traffic pilot has correctly replaced protection pilot	1 ms
(vii) Transfer time of diode i.f. switch at receive terminal	5 μ s

From this list it can be seen that there are two main functions involved, namely, the setting-up of the switching system prior to the actual change-over between main and protection channels, the time taken being called the operate time (items i-vi); and the physical change-over from main to protection channel, occupying a period called the transfer time (item vii).

In the above sequence the first function takes slightly in excess of 21 ms, while the second takes 5 μ s.

The effect on the continuity of the traffic path of switching is of great importance. As already mentioned, instantaneous equipment failure does not always occur, and, in practice, a high noise level will be detected before the traffic path is lost, and the 21 ms operate sequence will be completed before the

circuit has become completely unusable. Under such conditions, therefore, the only lost traffic time will be during the transfer of the receive i.f. diode switch, i.e. $5 \mu\text{s}$.

The acceptable lost circuit time will vary according to the type of traffic, and is typically 1 ms for telephony and television but shorter for data traffic. Thus, an i.f. switching system adequately meets the requirement, whereas a baseband switching system, which at the present time would have to use reed or high-speed electromechanical relays, would have a transfer time of the order of a few milliseconds and thus be less acceptable.

Of course, if the equipment failure were so rapid that the operate time of 21 ms could not be completed before the traffic path was completely disconnected, the lost traffic time would be longer than just the transfer time of the receive diode switch. In order to overcome this it would be necessary to reduce the operate time by, for instance, using wider bandwidths for the switching-tone circuits, speeding up the logic circuits, etc. In the ultimate, however, the operate time can never be less than the transmission delay between terminals. If the situation did occur that even this delay time was unacceptable, then the only solution would be to permanently feed the main and protection channels with the same information and simply have a receive terminal change-over switch. As pointed out earlier in this article, this is uneconomical since each working channel would need to have its own exclusive protection circuit.

From the maintenance point of view, the extremely rapid transfer time of the i.f. switch is advantageous, since a working circuit can be manually switched to a protection radio channel, even during periods of peak traffic density, with an almost undetectable break in transmission, to enable servicing of a radio channel between i.f. points to be carried out.

With regard to switching to protection modulators and demodulators it should be noted that, with the introduction of all-solid-state microwave equipment with the expected attendant increase in reliability, the rate of occurrence of change-overs due to failure of these units will be extremely low. Switching times will thus be less important.

For modulator switching, an i.f. diode switch is again used,

with a transfer time of $5 \mu\text{s}$ or less. The pilot detectors associated with this switch have operate times of 1 ms. Since, however, the change-over depends only on pilot-level variations the operate time will, in this case, not be masked by the delay due to a gradual noise increase, and the lost traffic time would thus be approximately 1 ms. Similarly, demodulator switching only occurs due to pilot failure. However, the change-over is then carried out at the output of the demodulator at the baseband frequency. The only suitable switches currently available are reed or high-speed electro-mechanical relays having a combined operate and transfer time of around 4 ms.

CONCLUSIONS

The system of duplication of repeaters for protection purposes as used in trunk cable systems does not lend itself to microwave radio-relay systems. Instead, it has been found convenient to allocate one or more broadband channels for protection purposes and to switch from working to protection channel at the terminal stations only.

A system of switching at i.f. is being introduced on some of the main inter-city routes since this system reduces breaks in traffic to the minimum and offers the facility of through connexion of broadband channels at terminals without the necessity to demodulate and then re-modulate.

ACKNOWLEDGMENTS

The author would like to thank the Transmission Division of the General Electric Company, Ltd., who developed the equipment described, and his colleagues in the Post Office for assistance in the preparation of this article.

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Book Review

"Fundamental Boolean Algebra." Professor J. Kuntzmann. Blackie and Sons, Ltd. xx + 320 pp. 75s.

This book is a translation of a French original, the work of the logical-algebra school of the University of Grenoble. Its aim is to help computer designers, and it starts from elementary definitions and works up to the synthesis of systems with several inputs and outputs, using different kinds of logical operator. In general, Boolean quantities are capable of taking three values, which correspond, say, to "false," "don't care," "true."

This is not a book for beginners, primarily because there is not enough introductory and explanatory text, especially in the examples. Practical engineers will find the book too theoretical. Theorists will find much to interest them, but will have a hard task in getting to grips with the material. They will be irritated at the general untidiness of nomenclature and notation (for example, the sign \vee denotes Boolean addition, but $+$ is used as often as not, even in the same expression as \vee , and \vee is sometimes used for arithmetic

addition; and certain definitions are such that one thing may be equal to, but less than, another); they will find so many misprints in formulae and tables that they will be reluctant to take anything on trust.

Some of the deficiencies have been introduced in producing the English edition, in particular the confusion between \vee and $+$; the original uses $+$ only. A count covering more than half the book suggests that all the misprints of the original have been reproduced, and about twice as many added. The translation of the text is good on the whole, although occasional mistranslations have produced misleading or incomprehensible statements. Translation of symbols might have been extended; C_r^n denotes the number of combinations of r things n at a time, which is liable to lead to confusion, and the English reader cannot be expected to know that $PPCM$ means LCM and $PGCD$ means GCD .

There are many interesting results in this book; it is a pity that a better job has not been made of presenting them.

W. E. T.

Telegraph Character-Storage Devices for Telex Services Routed over Radio-Telegraph Circuits

U.D.C. 621.377: 621.394.34: 621.394: 621.371

To enable radio-telegraph circuits incorporating automatic error-correction to be used for telex services some form of message storage is essential. Successive designs of equipment have aimed at greater reliability and reduced maintenance costs. A store that completely dispenses with mechanical parts has now been developed and is briefly described.

The technique of error-detection and correction (ARQ) on h.f. radio-telegraph circuits necessitates the storing of part (or all) of a telex message during the periods that the ARQ system carrying the telex circuit is "cycling," i.e. when the system has detected an error and is automatically requesting and receiving a repetition of the last few characters.

In the early 1950s the storage operation was carried out by the use of electromechanical fully-automatic reperforator transmitter distributors (FRXD's) using perforated paper-tape as the storage medium. These machines suffered from two disadvantages: when radio-circuit conditions were bad the loop of punched tape became very long and there was a risk of the loop becoming entangled or twisted, and, in addition, maintenance and operating costs were high.

The next stage of development was the introduction of the magnetic-drum store* in 1963, in which each drum unit provided independent storage for 4,000 characters on each of six circuits. This system has reduced the amount of attention necessary, but has a high capital cost that is partly offset by the reduced maintenance effort required.

More recently, storage equipments have been developed which use magnetic tape for storage. These equipments are provided as individual self-contained units using an endless loop of tape with a nominal capacity of 4,000 characters. Transistor and diode logic is used, and it is expected that each tape will require to be renewed not more frequently than once a year, hence little attention should be required.

All the systems mentioned so far have moving parts, and while satisfactory service is obtained there is some disadvantage in the periodic routines and adjustments which become necessary.

With this in mind, and with the aim of providing equipment with no moving parts, one manufacturer has developed a stored-program shared ferrite-core store operated by a

central processor. It is competitive in capital cost, and should require less maintenance effort than any of the previous systems.

A considerable saving in space is achieved, as one rack of the equipment provides storage for 15 circuits and accommodates the control circuit. The shared portion of the ferrite-core memory has a total capacity of 24,000 telegraph characters; thus, if each circuit is demanding storage simultaneously each is able to store 1,500 characters, equivalent to 3½ minutes of message time. The outage time of radio circuits has been reduced since the early days of ARQ, and it could well be that this number of stored characters will be sufficient in the future, but in any case, by arranging for the store to be shared by a mixture of good and difficult radio routes, it is unlikely that all 15 circuits would require storage simultaneously. At the other extreme, one circuit can have a maximum storage capacity of 8,000 characters when demand is low.

One of the advantages of the new equipment is its flexibility, for, by means of a control teleprinter, instructions, such as the maximum number of characters to be stored before the connexion is deemed lost and the call is released, or to monitor the input or output of the circuit, can be given for each circuit.

Information on the state of individual circuits, e.g. how many characters in store, or a copy of the actual characters in store, is printed-out on request.

A continuous-test program routines a majority of book-units of the central processor. For the failure of those which can cause complete stoppage of the unit, a manual diagnostic routine is applied, operated from a test panel which is provided on each rack of equipment.

Failure of the power supplies, or a complete equipment failure, operates the floor alarm. Other alarms are printed-out on the control teleprinter, together with the date and time.

Deliveries of the ferrite-core store commenced in September 1967 and it is planned to equip 75 radio circuits with this type of equipment.

C. S. H.

*ROBINS, J. M., and CROISDALE, A. C. An Electronic Telegraph Buffer Store Using a Magnetic Drum. *P.O.E.E.J.*, Vol. 56, p. 262, Jan. 1964.

Book Review

"Basic Industrial Electronics." Alfred Haas. Iliffe Books, Ltd. 208 pp. 203 ill. 7s. 6d.

This book was written in 1962 and it shows. The speed of development in this field is such that it is now out of date in its approach. The publishers' matter says that it is written "for industrial engineers whose initial training did not include electronics," but any such engineers reading this book will find it difficult to follow. This is primarily because the French author considers it logical (as stated on the fly-leaf) first to describe various industrial applications of electronics and then later in the book to describe electronic components. Many will find this approach annoying for it results in words,

which may be new to some readers, being mentioned and not explained until many pages later. For example, "multi-vibrators" are mentioned on page 62 but not described until page 69, "saturated reactors" are introduced on page 149 and not described until page 182. However, the book contains some quite worth-while descriptions of selenium controlled rectifiers (entitled in the book, quite correctly, semiconductor controlled rectifiers), saturated reactors and magnetic amplifiers. The sections on electronic heating and welding and on power conversion and control, are reasonably well written. If you already have some basic knowledge of electronics the book will form an introduction to applications in industry, but don't expect words to be explained before they are used or to assume everything the book says is correct.

C. E. E. C.

Trunk Transit Network: Access from Controlling Register-Translators at Group Switching Centres

R. H. G. KEARSLEY-BROWN, C.ENG., M.I.E.E., M.I.E.R.E., and W. S. CUMMING†

U.D.C. 621.395.374: 621.395.7

For calls via the trunk transit network, the controlling register-translator must present the stored digital information in a form suitable for subsequent transmission using multi-frequency techniques. A description is given of a new type of electromechanical register-translator, for use in non-director areas, that provides this facility. Details are also given of the modifications necessary to give transit-network access from earlier types of register-translators.

INTRODUCTION

Five types of controlling register-translator equipment are currently in use at group switching centres (G.S.C.s). The cold-cathode register-translator, Type 1, the electromechanical register-translator without fee switching, Type 2,¹ the electro-mechanical register-translator with fee switching, Type 3, and the magnetic-drum register-translator, Type 4,² have been in service since the introduction of subscriber trunk dialling (S.T.D.), and are designed to set up trunk calls by positioning switches under the direct control of Strowger pulses at a nominal 10 pulses/second rate. The Type 4 register-translator is used in director areas, the remainder in non-director areas.

For calls routed via the transit network,^{3,4} one of the basic requirements of the controlling register is to present the stored digital information in a form suitable for subsequent transmission using multi-frequency signalling techniques. A new electromechanical register-translator with fee switching, Type 5, which has recently been developed for use in non-director areas, includes this facility. By modification of the register and translator circuits, and by the provision of auxiliary equipment, it is possible also to provide transit-network access from the Type 2, Type 3 and Type 4 equipments; methods of providing similar access from the Type 1 version are being examined.

The following description outlines the circuit operation of the Type 5 equipment on both Strowger and transit-routed calls, and gives details of the circuit modifications necessary for transit-network access from the Type 2, Type 3 and Type 4 equipments.

GENERAL DESCRIPTION OF TYPE 5 CONTROLLING REGISTER-TRANSLATOR

Fig. 1 shows the main elements of the Type 5 controlling register-translator.

Digit Storage

During the inter-digital pause following the initial digit 0 of the national number, a register-access relay-set is seized, causing its associated register hunter to find a free register. Under adverse conditions the combined hunting times of the 1st selector and register hunter may exceed the inter-digital pause, and it is necessary to store the next dialled digit in the register-access relay-set; the succeeding dialled

digits are repeated by the register-access relay-set directly to the incoming stores of the register.

As soon as complete receipt of the digit stored in the register-access relay-set has been established, this digit is transferred into its appropriate register store. Since separate paths are provided for initial-digit transfer and reception of the following digits, these processes can continue simultaneously.

Translation

On receipt of the first three digits, the register makes its first application to a translator, which is shared by a group of registers. When discrete register-to-translator association has been achieved, the three digits stored in the register are marked into the translator in binary form. If the 3-digit code provides sufficient information to determine the destination of the call, a translation is given; if, however, identification of the 4th digit, or 4th and 5th digits, is also required, operation of a translation relay is deferred and a signal is returned to the register to indicate that re-application should be made when the required information is available in the register.

Register Sending Program: Strowger

After translation of the code, the following information is returned to the register.

- (a) A metering digit to indicate the charge rate applicable to the call.
- (b) Up to two routing digits, on each demand to the translator.
- (c) A signal to indicate that the call is to be routed via the Strowger trunk network.
- (d) A sending program, on Strowger-routed calls, to indicate which digits of the stored national number are to be sent following transmission of the routing digits, and the length of the inter-digital pauses (i.d.p.s) to be applied between digits.

On receipt of this information, the register releases the translator, which then becomes available for use by other registers.

The metering digit is sent to the register-access relay-set to set the appropriate charging rate for the call, and, at the same time, the first of the routing digits is pulsed-out to step the first trunk selector. If two routing digits are returned to the register on the first demand, the second of these is sent following an i.d.p.

A second demand is made to the translator, if necessary,

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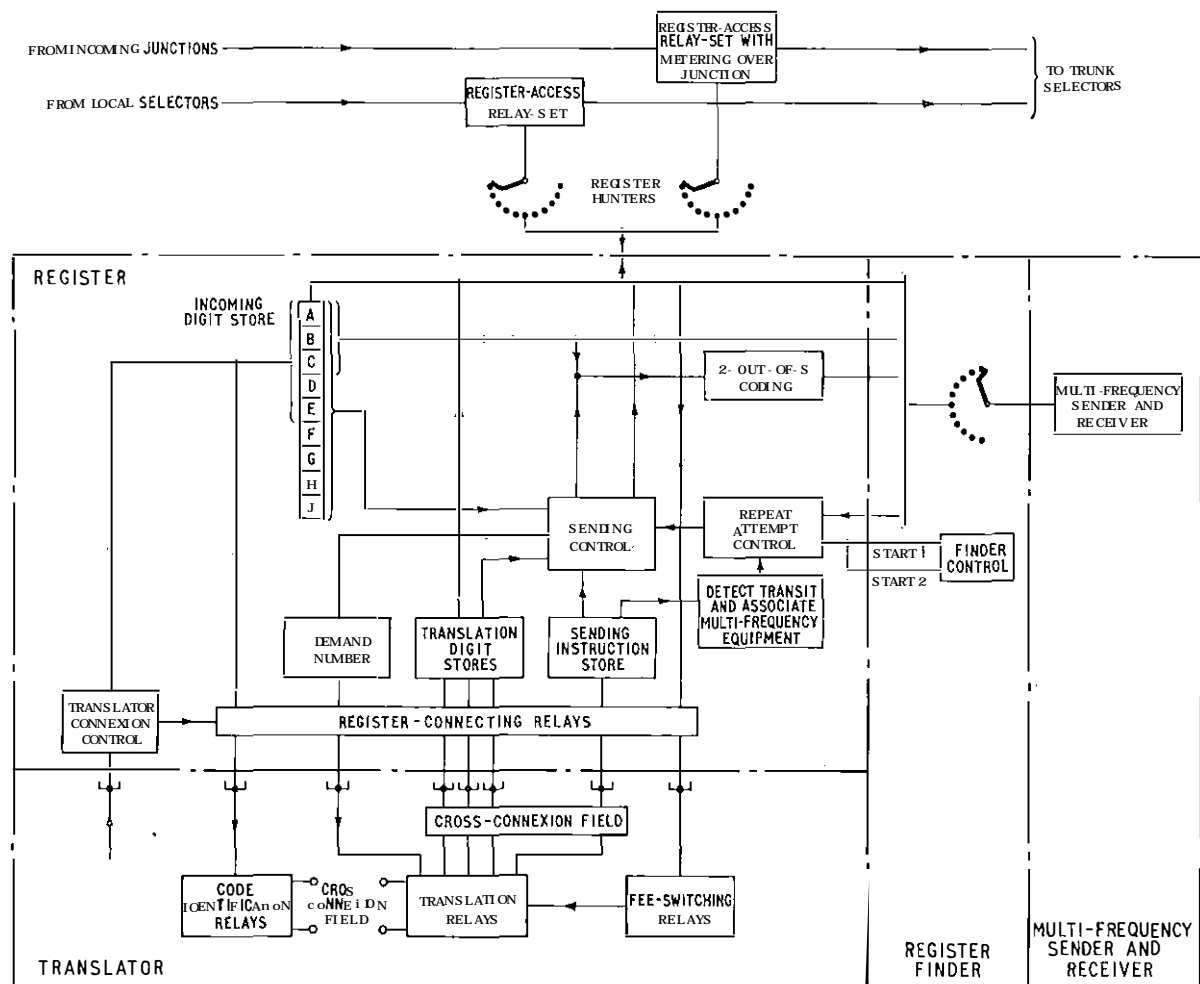


FIG. 1—Block schematic diagram of Type 5 register-translator

when the second routing digit has been sent, and up to two routing digits may again be received in the register. After these have been transmitted, a third and final demand may be made to obtain the 5th, or 5th and 6th, routing digits. In all instances, the last routing digit is accompanied by a signal from the translator to the register, indicating that no further demands are required.

The sending program received from the translator indicates whether the call is to be routed (a) on a wholly Strowger basis, or (b) via the trunk transit network. If (a) applies, the sending program will also indicate which of the stored digits are to be transmitted following the routing digits: for example, on a call to a director exchange other than in London, sending will normally commence with the third digit stored in the register. The sending program also controls the duration of the i.d.p.s to be introduced at various stages in the sending sequence. On calls to director exchanges, a lengthened i.d.p., nominally of 1,350 ms duration, follows the transmission of the last routing digit to allow association of terminal register equipment at the objective G.S.C.; the digits which then require to be forwarded in order to complete the call are separated by shortened pauses of 350 ms. On calls to non-director exchanges, a normal i.d.p. of 750 ms follows the final routing digit and all subsequent digits.

On S.T.D. calls the maximum number of dialled digits that may be received by the register is nine; national numbers may, however, consist of seven, eight, or nine digits. On Strowger-routed calls it is necessary to determine the point at which it can be assumed that the complete information for setting up the call has been received in the register, in order that the equipment can be released after transmission of the last stored digit. On 9-digit calls, the end of dialling can readily be identified, since the maximum storage capacity is utilized; on

7-digit or 8-digit calls the method adopted involves provision of a time-out following receipt of the 7th digit. A period of 4 seconds is allowed against the possible receipt of an 8th digit. If an 8th digit is not received within this period, or if a 9th is not received within 4 seconds of receipt of the 8th, completion of dialling is assumed and the register is released following transmission of the last stored digit. The facility is also provided on Strowger-controlled calls of restraining the transmission of the 6th, 7th or 8th stored digits. Restraint of sending is necessary since on calls to 11-and-over P.B.X. groups, the last digit dialled is ineffective and a call could be answered before the last digit had been transmitted from the register. These last digits of the national number are, therefore, transmitted in sequence only when the end of dialling has been established, either by receipt of nine digits, or by expiry of the 4-second time-out period.

Register Sending Program: Transit

If the sending instruction returned from the translator to the register indicates a transit routing, a start signal is given to a common allotter circuit for association, via a register finder, of a free multi-frequency (m.f.) sender and receiver. At the same time, the metering and routing digits are signalled to their appropriate stores in the register and the translator is released. The routing digits are transmitted at a nominal rate of 10 pulses/second to position the local trunk selectors, and, when the trunk route has been seized, the outgoing negative and positive wires in the register are diverted to the m.f. sender and receiver.

From this point, all digital information to be forwarded from the register is signalled, in 2-out-of-5 form, to the m.f. sender and receiver in response to either "transit proceed-to-send" or "terminal proceed-to-send" signals received from

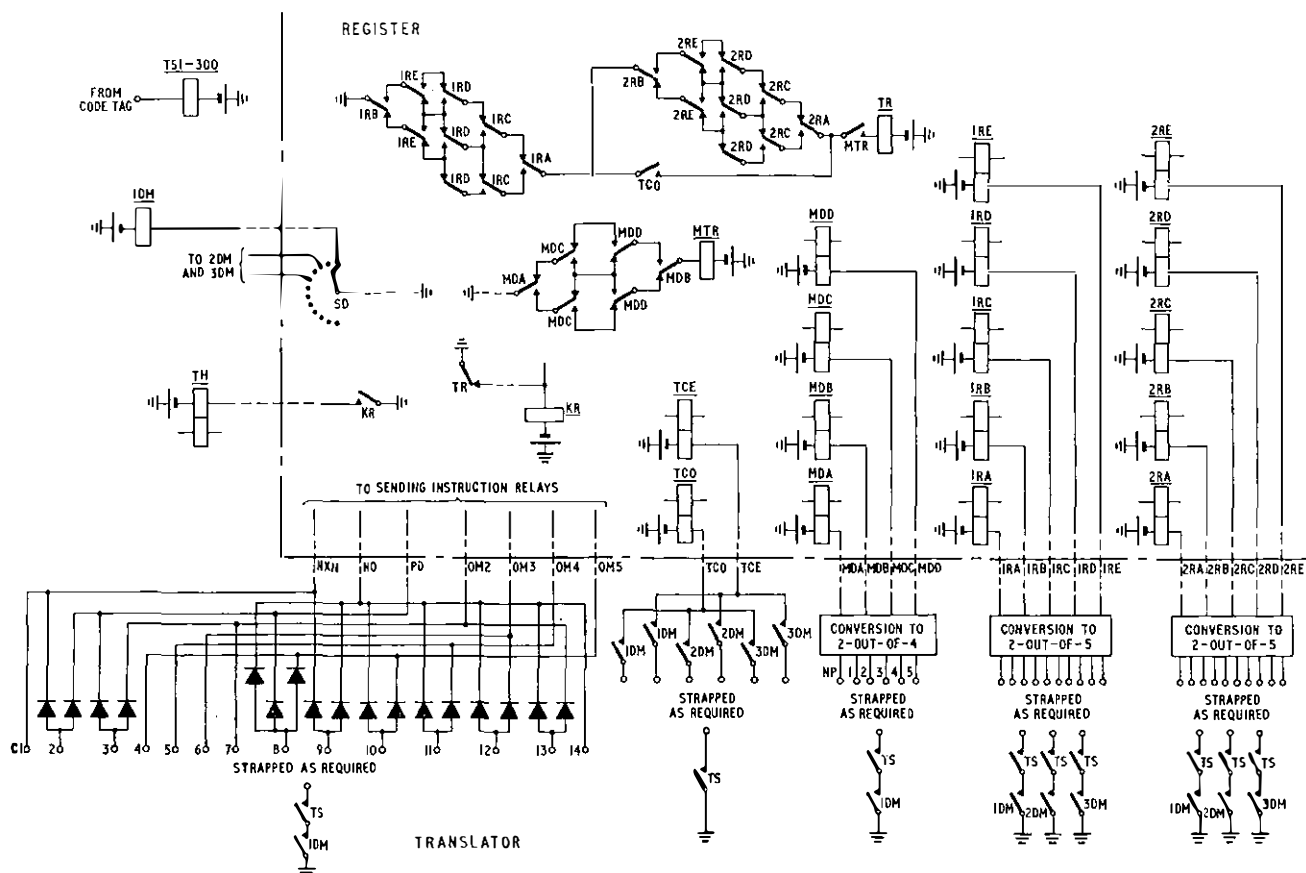


Fig. 3—Transfer of translation information to register

5th, or 5th and 6th, digits. The operation of relays 2DM and 3DM is controlled by an arc of the send-distributor switch SD, which steps when the previous translation information has been pulsed out from the register. In all instances, the last routing digit, when signalled to the register, is accompanied by an end-of-translation signal TCO or TCE. Relay TCO operates if only one routing digit is returned on the final demand, and a contact of this relay short-circuits the self-checking contact chain associated with the 2RA-2RE group of relays. Relay TCE operates if two routing digits are returned on the final demand. Operation of either of these relays indicates to the register that no further application to the translator need be made.

Register Sending Program : Strowger

When the translation information is received in the register (see Fig. 4) circuits are completed for self-interacting relays PR and PM. Relay PR pulses at 10 pulses/second to step send-switch S, and loop-disconnect pulses are sent via the outgoing negative and positive wires. At the same time, relay PM pulses at 14 pulses/second to step meter-digit control-switch MS and unselector AR in the register-access relay-set. Sending terminates in both cases when the marking for the digit to be transmitted is reached, relay SZ operating via arc of unselector S and relay MZ via arc of unselector MS. A contact of relay SZ completes a circuit for a timing element which prevents the sending of a further digit until relay PT operates after an i.d.p. of 750 ms. However, during the sending of the local routing digits, the normal i.d.p. may be shortened if the switching of the trunk selector to the next stage is detected by the momentary release of relay HSD. The release of relay HSD allows relay SDA to operate, and the i.d.p. is terminated after a further period of 150 ms.

The sequence in which digits are sent is controlled by unselector SD, which steps once for each operation and release of relay SZ and its relief relay, SZR. When the last routing digit is signalled from the translator the appropriate

translation-complete relay, TCO or TCE, operates, and when this digit has been sent to line, relay TDS operates.

The sending instruction previously received on relays NXN, OX, OY and OZ then causes the SD unselector to self-drive to the outlet corresponding to the next digit to be transmitted.

On Strowger-routed calls, sending of loop-disconnect pulses under control of the send-switch continues until all the stored digits have been sent, when unselector SD steps to contact 15 and relay CO in the register-access relay-set operates. The operation of relay CO results in switch-through of the call and release of the register.

Register Sending Program : Transit

If the translation information indicates a transit-network routing, the metering and routing digits are received in, and sent by, the register as for a Strowger call, but the sending-instruction signal operates relay NXN (see Fig. 4). A start signal is connected, via a register finder, for association of a m.f. sender and receiver. Relay MFC operates when a free sender and receiver is connected to the calling register, and, when the last routing digit has been sent, relay MFD operates to switch the outgoing negative and positive wires from the register to the sender. All subsequent digital information necessary for completion of the call is made available to the sender in 2-out-of-5 form, using a denary to 2-out-of-5 coding matrix, as shown in Fig. 5. In response to transit proceed-to-send signals, earth is connected from the sender and receiver to leads D1, D2 and D3 at 80 ms intervals, and the A, B and C digits are marked out to the sender.

Digits to be repeated to the objective G.S.C. are marked to the sender, via the coding matrix, in response to signals received on lead DX. Relay DX operates for the duration of each terminal proceed-to-send signal received. The digit to be transmitted is controlled by send-distributor unselector SD, which steps to its next outlet when the signal is disconnected from lead DX by the m.f. sender and receiver. The first digit to be transmitted is the B digit for calls to London director

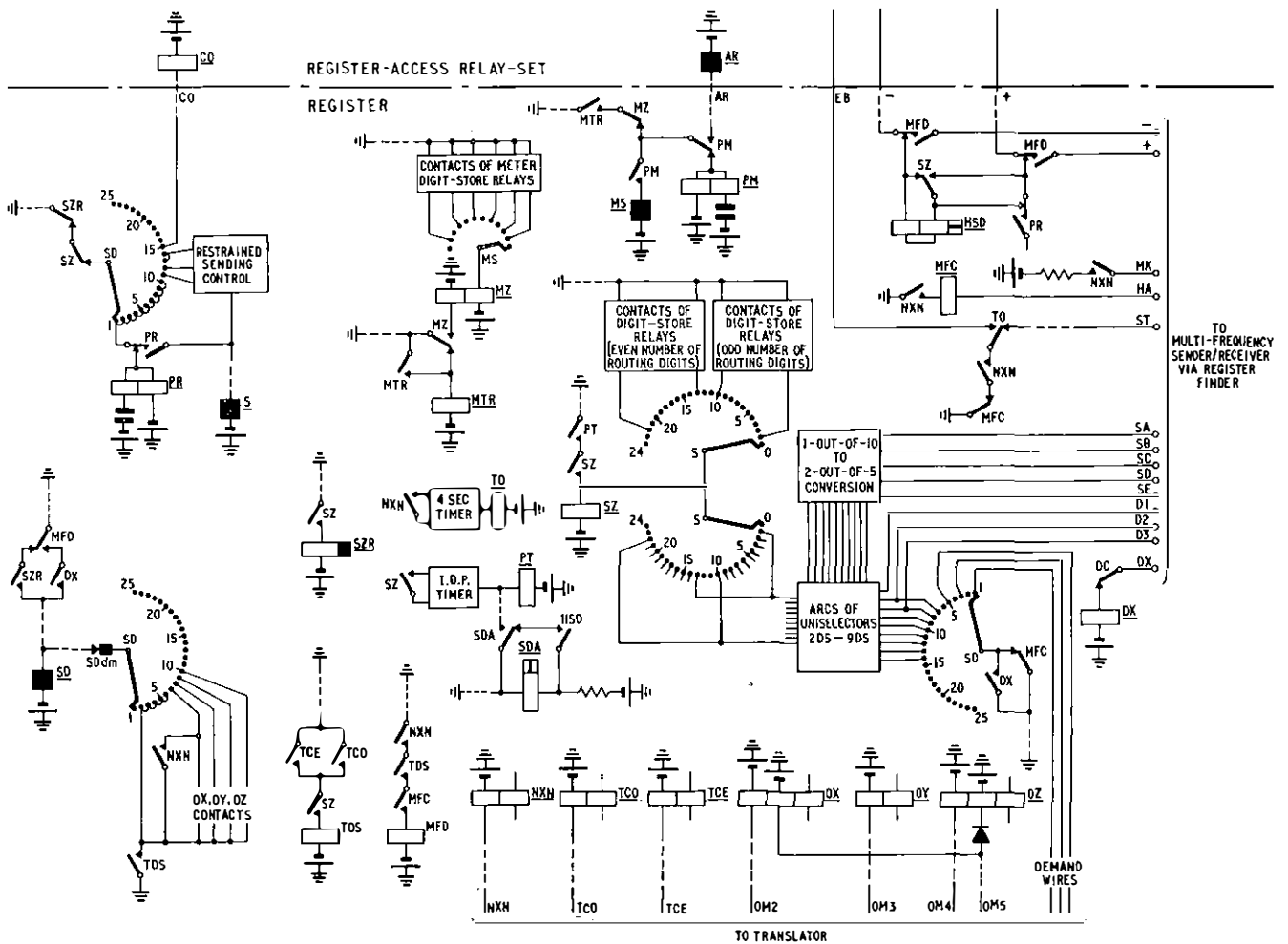


FIG. 4—Register sending control

exchanges or the C digit in all other cases, the send-distributor being appropriately positioned following transmission of the last routing digit. The remaining stored digits are sent, one at a time, in response to each subsequent terminal proceed-to-send signal. The register and associated equipment arc released, and the transmission path switched through, when a number-received signal is connected via lead NR to operate relay CO in the register-access relay-set. If a spare-code

signal is returned from the m.f. sender and receiver, N.U. tone is connected to the calling line by the register-access relay-set in response to an earth signal connected to lead NU of the register. The register relay-set then initiates clear-down of the register equipment.

Fig. 6 shows the register element which functions on receipt of a repeat-attempt signal from the sender and receiver via lead RP. Relay RP operates, and its hold coil is connected

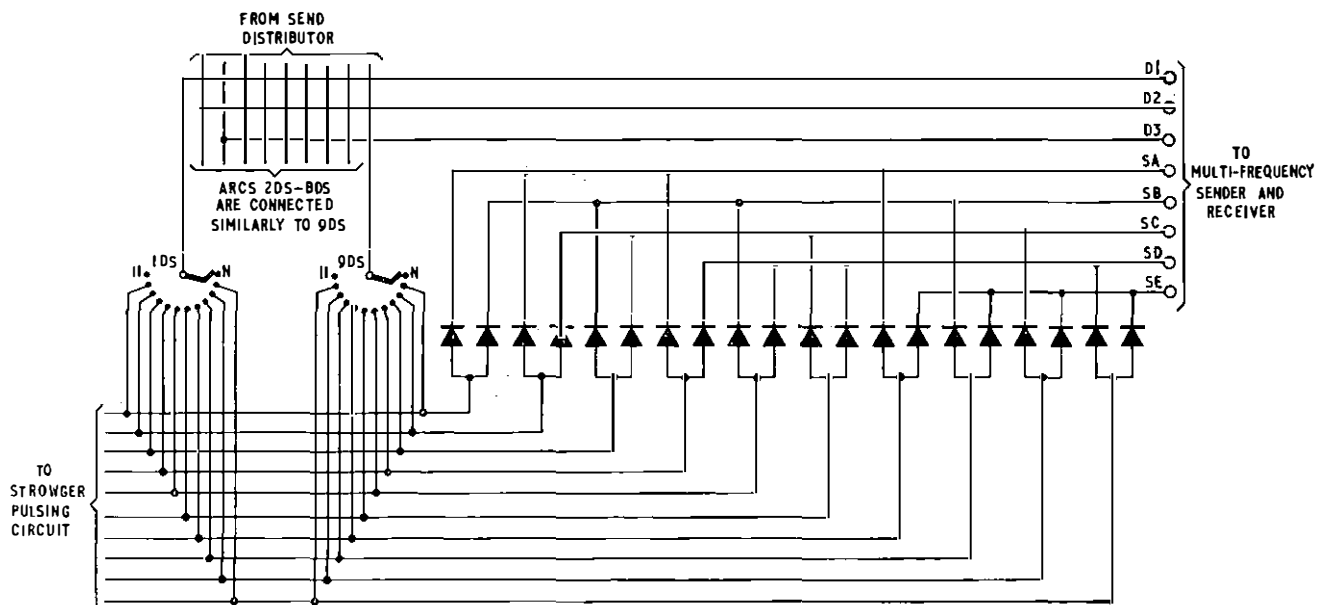


FIG. 5—Denary to 2-out-of-5 coding matrix

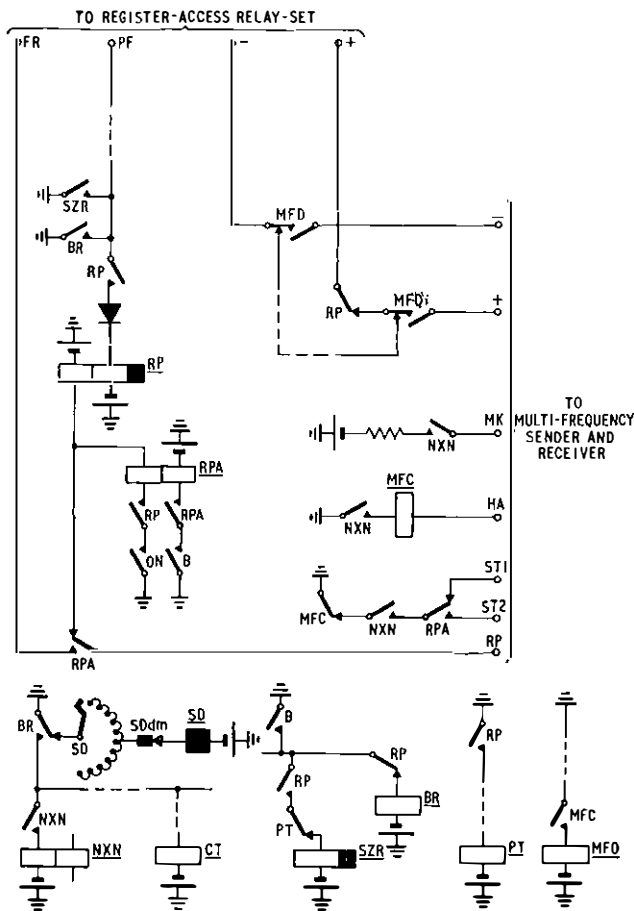


FIG. 6--Register repeat-attempt element

to a contact of relay SZR and to lead PF. The outgoing loop is opened, the translation-information relays are released, and the send-distributor is driven to its home contact. When the RP signal is disconnected by the sender, relay RPA operates to prepare a forced-release circuit should the second attempt to complete the call also fail. Relay RP releases when the local trunk selectors and the register send-distributor have restored to normal, and re-application is made to the translator for the routing and sending information, the meter-digit leads being disconnected by contacts of relay RPA. When the translation information is again received in the register, a signal is connected to the second of the common start leads in order that an m.f. sender and receiver in an alternative group may be associated.

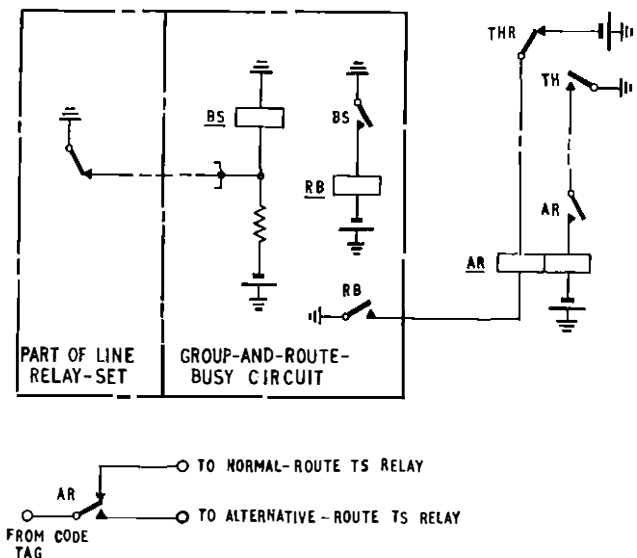


FIG. 7--Alternative routing

Alternative Routing

The element providing the alternative-routing facility is shown in Fig. 7. When the last outgoing trunk circuit in a particular group is taken into use relay BS in the group-and-route-busy circuit operates and connects a signal to operate the AR relay in each translator. When a demand is made by a register, the marking of the code point is switched to an alternative-translation relay.

Charging-Group Discrimination

The translator provides for fee-digit discrimination for calls originating from dependent charging groups. The meter digit can be varied, according to the charging-group discrimination signal received from the register-access relay-set, for (a) a maximum of 80 translations with the choice of two fees, or (b) a maximum of 40 with a choice of three fees, or any intermediate combination of (a) and (b). Fig. 8 illustrates the circuit principles. The discrimination signal from the register-access relay-set is provided by strapping lead FS to either a 2,200-ohm or 150-ohm battery. Relay FA operates to the 2,200-ohm battery condition, and contacts of its relief relay, FAA, connect earth signals via the cross-connexion field to operate the requisite number of F relays. Each operated F contact in the cross-connexion field switches the marking lead from its normal to an alternative meter-digit tag, and, when the translation relay TS operates, the appropriate digit is marked to the register.

If the discrimination signal received from the register-access relay-set is -50 volts connected via 150 ohms, relays FA and FB operate. A contact of relay FB renders relay FAA ineffective, and the F relays connected to the contacts of relay FBA cause a second group of meter-digit leads to be switched.

Translator Change-over

Each translator serves a maximum of 28 registers, but groups of registers and their associated translators are interconnected so that when a translator fails, or is taken out of service for maintenance purposes, its group of registers is switched to another translator.

Fig. 9 shows, in simplified form, the switching of a group of registers from the normal translator to the next translator in the chain. This translator will now carry the traffic of the group of registers associated with the previous translator together with the traffic of its own group of registers.

In the event of a translator failure, relay AL is operated, and, provided there is another translator available, relays ALA and PCO operate: relay ALA operates the deferred alarm, and relay PCO prepares a circuit for relay CO and disconnects earth potential from tags SCD1 and SCD2. When relay TH releases, indicating that the translation and associated relays are released, relay CO operates and its contacts transfer all the common leads from the group of associated registers to the next translator.

If an alarm condition occurs on the last translator in service, relay AL is operated as before, but relays PCO and ALA cannot operate as earth is removed from tags SCD1 and SCD2 by contacts PCO1 and PCO6 in the other translators. Relay ALA remains normal and a prompt alarm is given. The translator is not changed over but remains in service displaying an alarm.

Timing Circuits

For the timing of i.d.p.s between the transmission of Strowger digits, the Type 5 register employs a transistor-type element. Three timing periods are provided, of 350 ms, 750 ms and 1,350 ms nominal duration, and are applied as required under control of the sending program received from the translator. A similar element providing a 4-second timing period is used on Strowger-routed calls for the end-of-dialling indication, and on calls routed via the transit network for the timing of the period allowed for association of an m.f. sender

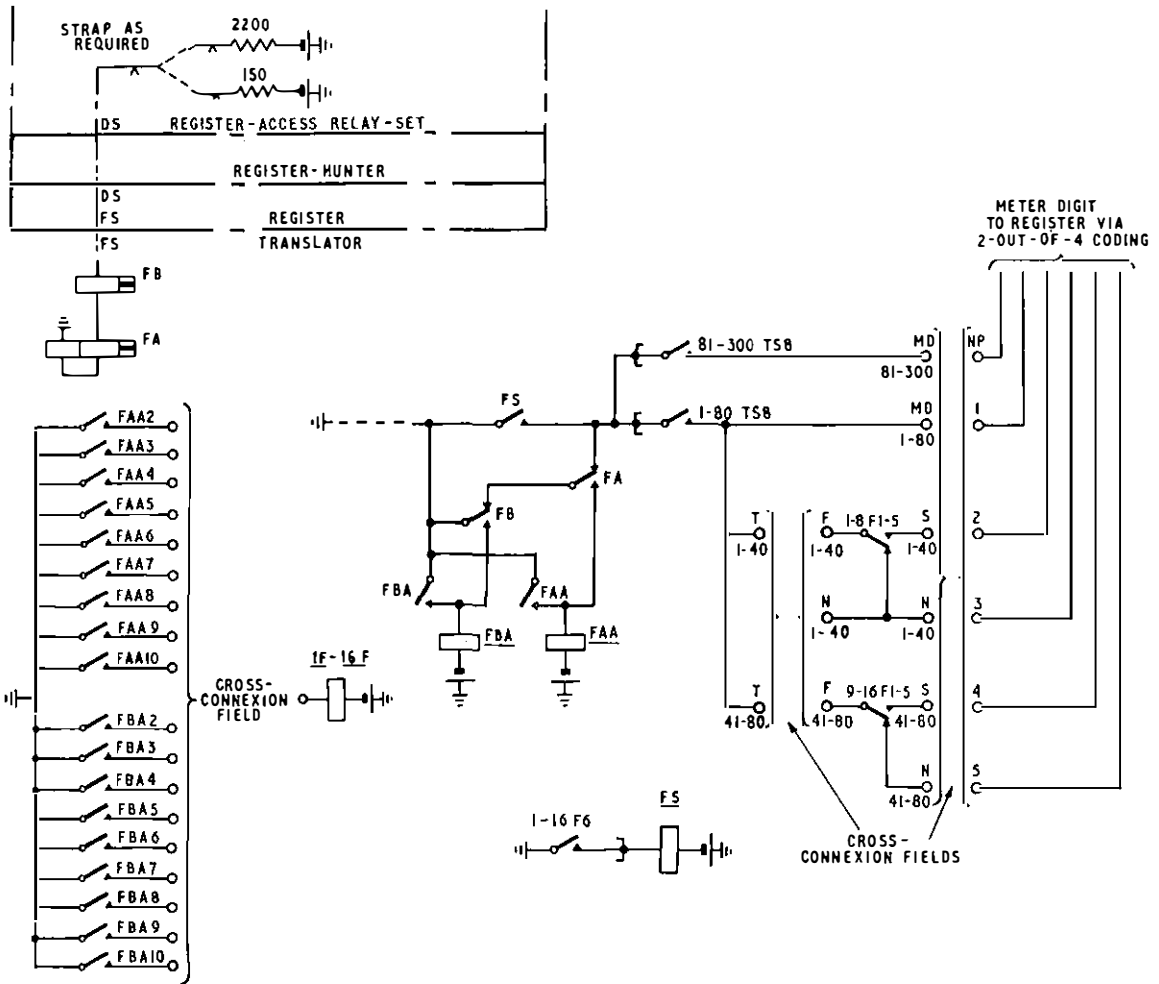


FIG. 8—Charging-group discrimination

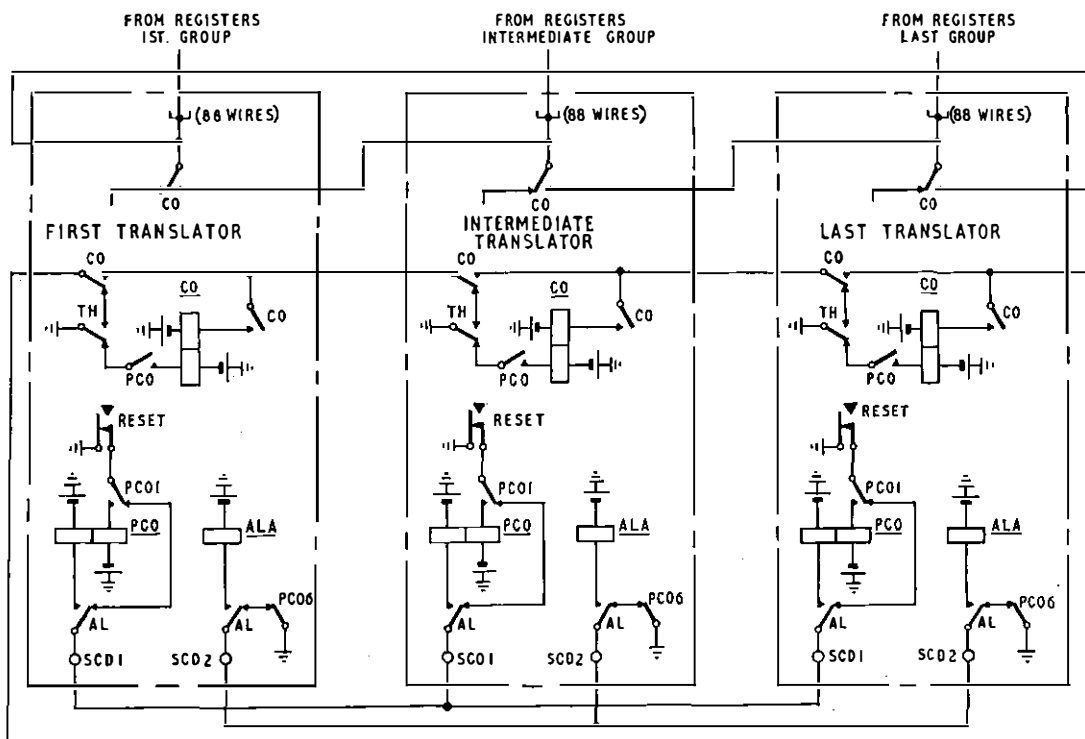


FIG. 9—Translator change-over

and receiver. In the translator, a timer employing the same principles is used for the timing of a 1-second period following seizure of a translator. If the translator is not released within this period it is taken out of service and its associated registers are transferred to the next translator in the group.

Register Finder

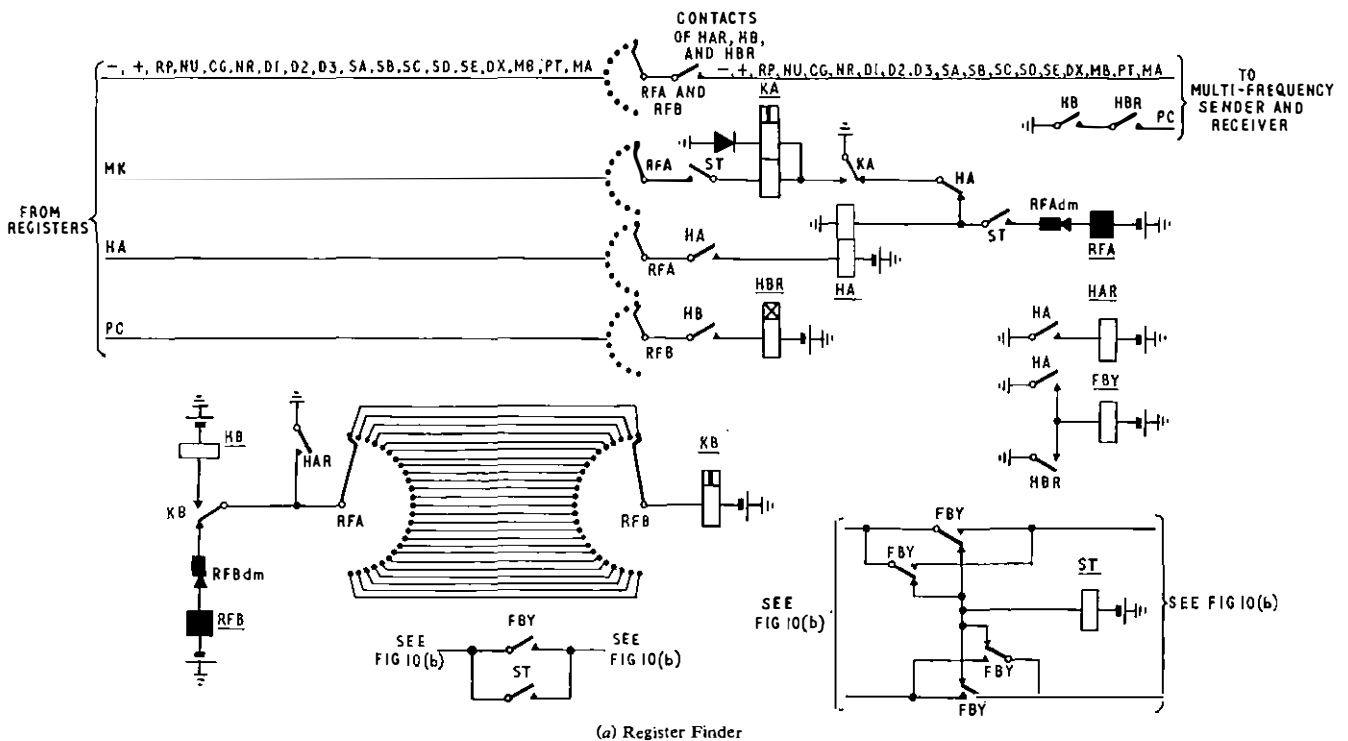
Each group of up to 25 controlling registers is served by a common group of m.f. senders and receivers. The number of senders and receivers provided at any installation depends upon the proportion of traffic which is to be routed via the transit network.

Register groups are divided into sub-groups, the number of sub-groups being equal to the number of m.f. senders and receivers. Associated with each sender and receiver is a 25-outlet unselector-type finder, the outlets of which are wired so that each sender and receiver serves, as first choice, approximately the same number of registers. If the first-choice circuit is busy, the "finder-start" signal from the calling register is transferred by a chain allotter to the first free finder in the group. By the provision of two common start leads from each register, it is arranged that first-attempt and

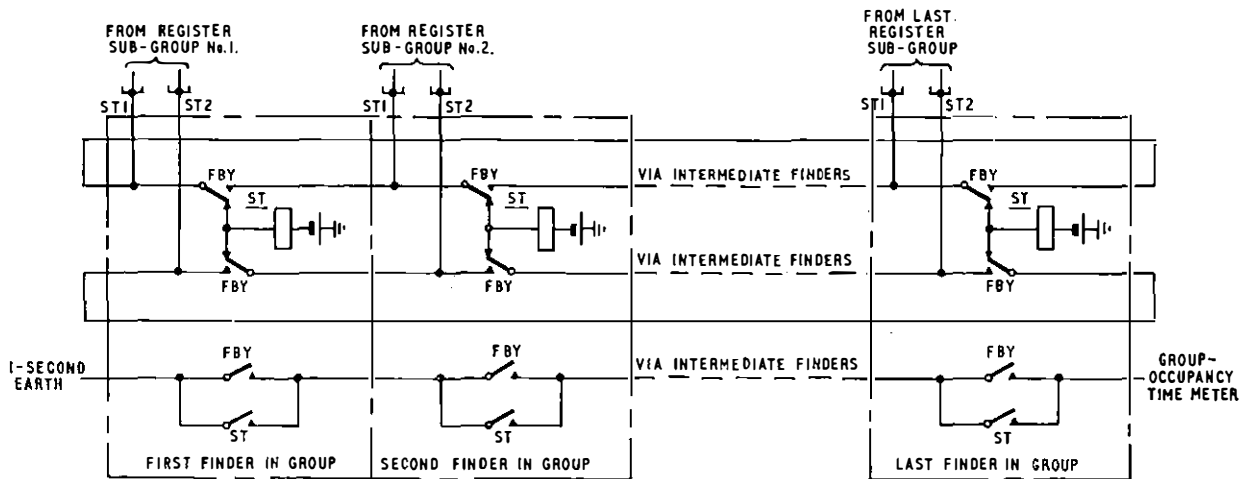
repeat-attempt calls from registers utilize different m.f. senders and receivers and finders.

Fig. 10 shows the circuit arrangements. When the register receives translation information indicating that the call is to be set up via the transit network an earth signal is connected to the common start lead ST1. Two start wires are provided per register sub-group, the ST2 common lead being used for seizure of an alternative m.f. sender and receiver under repeat-attempt conditions. If the first-choice m.f. sender and receiver is free, relay ST operates and causes uniselectors RFA and RFB to step in sequence to find the calling register, which is denoted by -50 volts on the MK lead. When the marked outlet is reached, relay KA operates to cut the unselector drive circuit, and relays HA, HAR and HBR operate to switch the signalling leads from the register to the m.f. sender and receiver. Relay FBY in the allotter circuit operates, and the common start wires from the register sub-group are diverted to the ST relay of the first free finder in the chain. The switching relays in the finder are released, either on clear-down of the register or following receipt by the register of a repeat-attempt signal.

The register finder described is also suitable for use with



(a) Register Finder



(b) Finder Allotter

Fig. 10—Register finder and finder allotter

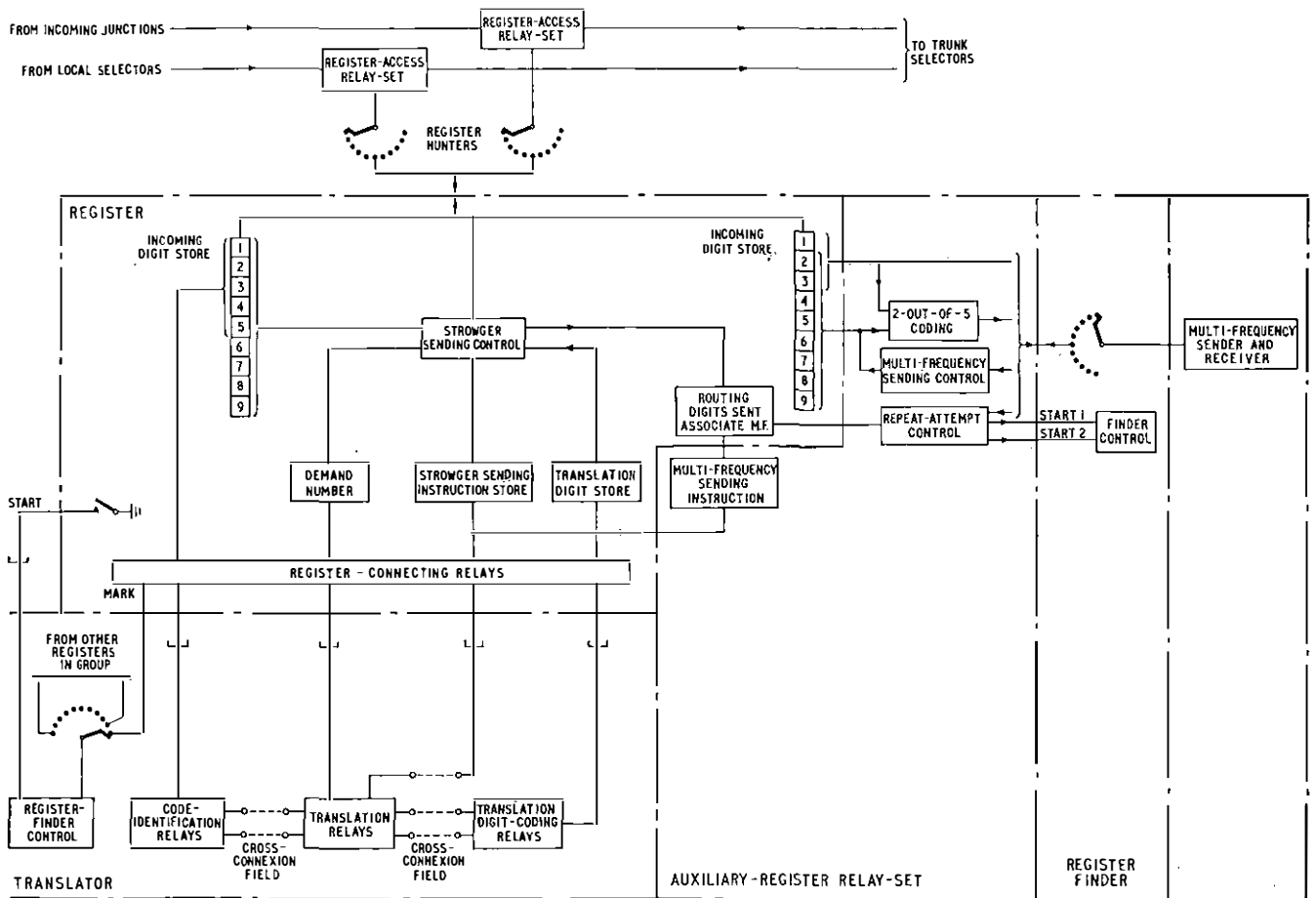


FIG. 11—Block schematic diagram of Type 2/Type 3 equipment

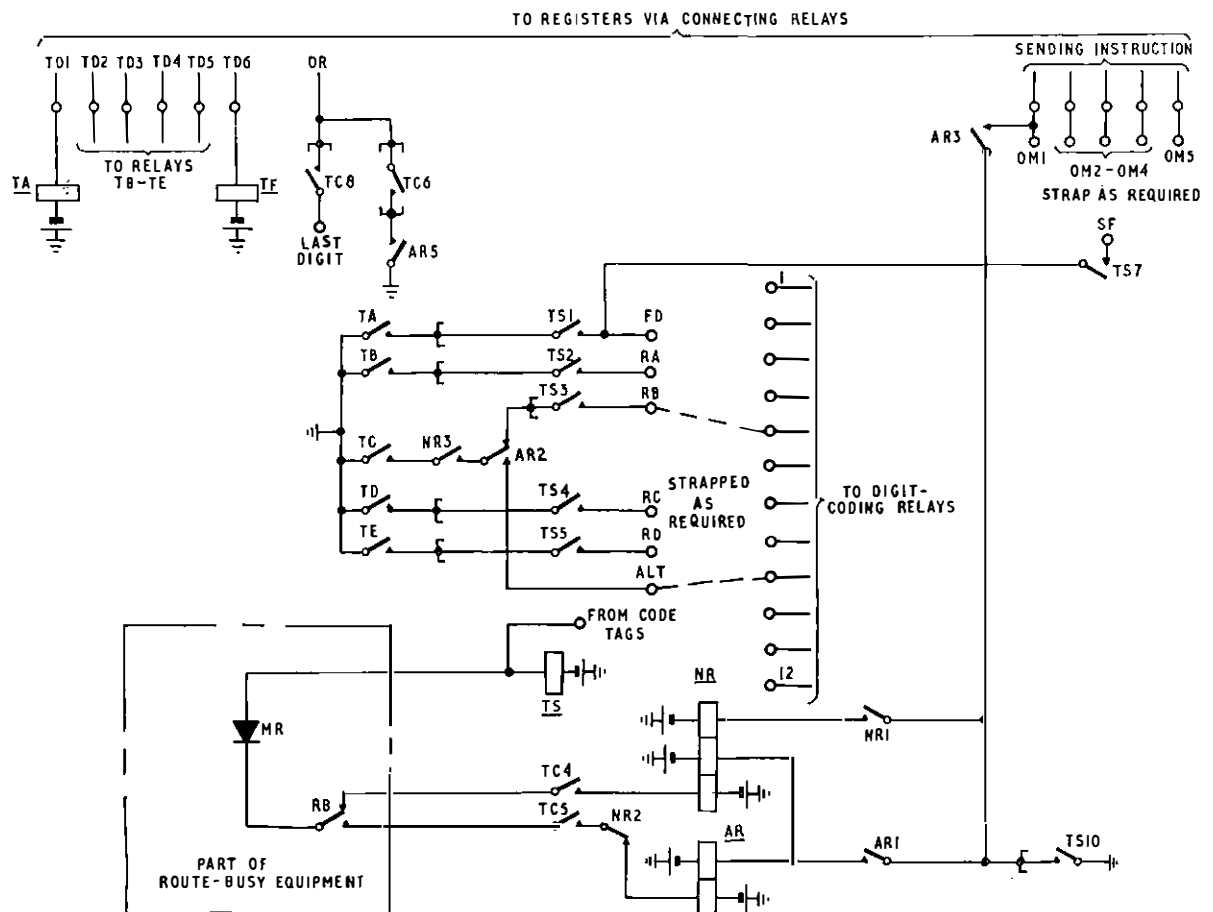


FIG. 12—Transit-call identification and typical alternative routing (Type 2 and Type 3 equipment)

the Type 2 and Type 3 register-translator equipments, for access to the m.f. sending and receiving equipment.

MODIFICATION OF TYPE 2 AND TYPE 3 REGISTER-TRANSLATORS FOR TRANSIT WORKING

Translation

Fig. 11 shows, in schematic form, the main elements of the existing equipment together with the additions necessary for routing calls via the transit network. Since space limitations preclude the inclusion of further components on the register mounting plates, auxiliary register relay-sets are provided. These are mounted on conventional relay-set racks remote from the main equipment, and are associated with m.f. sending and receiving equipment via register finders.

Fig. 12 shows the element concerned with transit-call identification. When a register is connected to the translator, a signal is connected to the demand relays to indicate which translation digit is required. Relay TA operates for the fee digit, relay TB for the first routing digit, relay TC for the second routing digit, and so on. The translation relay TS operates when the dialled code has been identified, and earth potential is connected via the translation field to operate the appropriate translation-digit relays. In addition to the fee and routing information, a sending instruction is signalled to the register: on a Strowger-routed call, this signal will be connected to one of the leads OM2-OM5; on a transit-network

call, the original function of lead OM1 has been altered to provide a signal for association of m.f. sending equipment.

Translation relays for basic routes on which the alternative-routing facility is required are mounted on modified plates. The facility provided is alteration of the value of the second or third routing digit on receipt of a monitoring signal indicating that all circuits are busy in any given basic route. The switching relays, designated NR (normal route) and AR (alternative route), are connected to the route-busy equipment associated with a group of outgoing trunk circuits (see Fig. 12). Relay RB, if operated when the translator is connected to the register, completes a circuit for relays AR and NR. The alternative digit is then marked to the register via contacts NR3 and AR2, and, at the same time, a contact of relay AR signals the transit-call indication via lead OM1. If relay RB is normal when application is made to the translator, relay NR operates to signal the routing digit appropriate to the basic route.

Circuit Operation for Transit Call

On receipt of the "transit" signal via lead OM1, relay NXN in the auxiliary register relay-set operates (see Fig. 13). After the last routing digit has been sent, and following an i.d.p., the send-control uniselector, SC, is stepped to contact 6 and relay NXO operates. Contacts of relay NXO complete "start" and "mark" circuits for association, via a finder, of a free m.f. sender and receiver. When the calling register has been found,

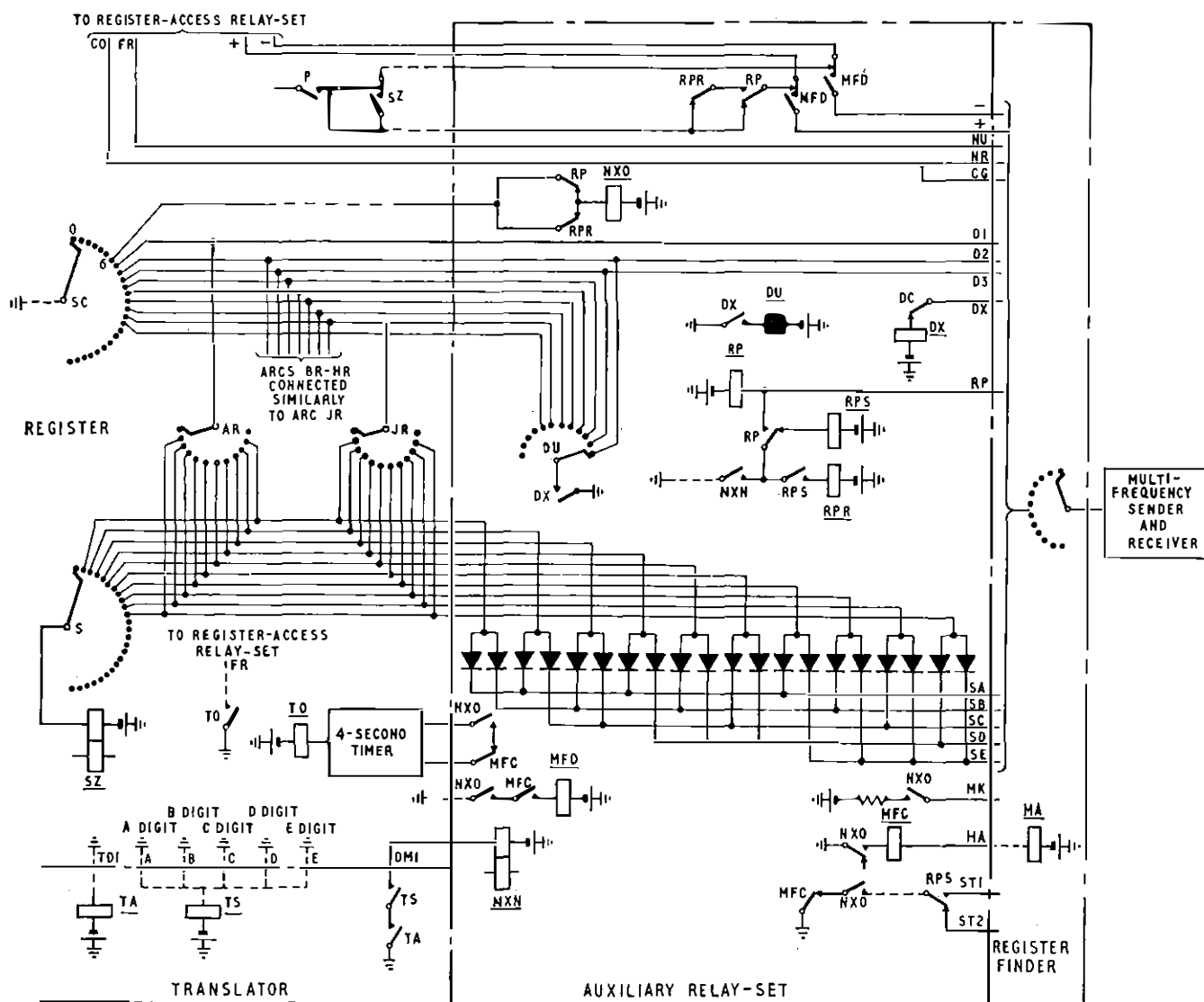


FIG. 13—Circuit element for transit-network call (Type 2 and Type 3 equipment)

relays MFC and MFD operate and the outgoing negative and positive wires are diverted to the m.f. sender and receiver.

Following operation of relay NXO, a period of 4 seconds is allowed for association of the m.f. sender and receiver and is provided by a transistor-type timer as used in the Type 5 equipment. This timer is also used for the end-of-dialling indication on Strowger-routed calls, replacing the original element which, for this function, utilized the CR digit-switch in conjunction with 1-second earth pulses.

If association has not been effected in the 4-second period following operation of relay NXO, relay TO operates to connect a forced-release signal to the register-access relay-set, N.U tone is returned to the caller, and the register equipment is released. The principle of digit marking to the sender is similar to that used in the Type 5 equipment, the A, B and C digits being marked in 2-out-of-5 form in response to transit proceed-to-send signals connected to the D1, D2 and D3 leads. Relay DX operates for each terminal proceed-to-send signal received, and the digits are marked in sequence to the m.f. sender under control of distributor DU.

Repeat Attempt

If, during the setting-up of a call, a repeat attempt is initiated by the outgoing sender and receiver, relay RP operates. Contact RPI releases relay NXO, which in turn causes the release of relays MFC, MFD and the switching relays in the register finder. The m.f. sender and receiver is thus dissociated from the register, and the negative and positive wires are disconnected to release the route set up forward of the outgoing line relay-set. The duration of the disconnection period is controlled by the combined release times of relays RPS and RPR. With relay RPR normal, the outgoing loop is re-connected to re-seize the trunk route and relay NXO re-operates to initiate association of an alternative m.f. sender and receiver. With relay RPS normal, the start signal to the register-finder allotter is applied to the second of the common leads to allow association of a m.f. sender and receiver in a group different to that used on the first attempt.

When the terminal incoming m.f. register recognizes receipt of the last digit of the objective exchange, a number-received signal is returned to the outgoing m.f. sender and receiver, which in turn connects an earth signal via lead NR to operate relay CO in the register-access relay-set. Relay CO operating, switches the call through and releases the register. A similar sequence occurs if a "congestion" signal is returned from a T.S.C. to the outgoing m.f. sender and receiver, but in this instance the call is switched through to a verbal announcement. If the dialled number is spare, the terminal register returns a signal which results in the connexion of earth to lead NU and the operation of relay M in the register-access relay-set. N.U. tone is returned to the caller, the outgoing route is cleared, and the register and associated equipment are released.

MODIFICATION OF TYPE 4 REGISTER-TRANSLATOR FOR TRANSIT WORKING

The scheme used for access to the trunk transit network from the magnetic-drum type controlling register-translator differs fundamentally from that used at non-director G.S.C.s. A call to be routed via the transit network is recognized, not by an instruction from the translator, but by a signal returned by a m.f. outgoing line relay-set on its seizure, following transmission of the local routing digits. This method reduces the modifications necessary within the electronic equipment, but, nevertheless, the provision of m.f. sending facilities requires the addition of a m.f. control circuit, together with modifications to the register relay-sets and some of the existing electronic-equipment panels.

Outline of Operation

Fig. 14 shows, in schematic form, the additional equipment required at director-area G.S.C.s to allow access to the transit network. When a register-access relay-set is seized, following the initial digit 0, a register relay-set is associated via a register hunter. The remaining digits of the national, or international number, are then pulsed via the register relay-

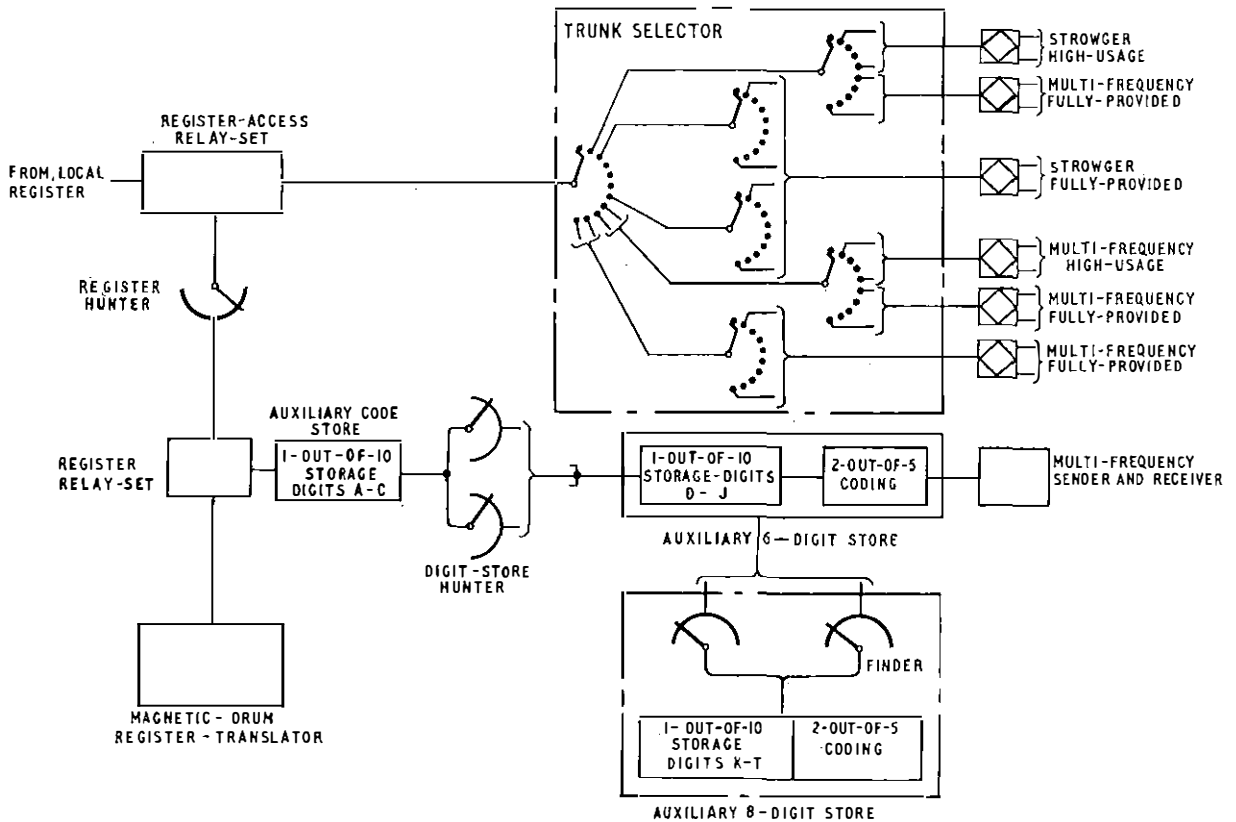


FIG. 14--Block schematic diagram of Type 4 magnetic-drum register-translator

set into the corresponding electronic register, but, additionally, the A, B and C digits are repeated into an auxiliary code store. One auxiliary code store is required for each of the 47 registers provided on a fully-equipped magnetic-drum register-translator.

When sufficient digits have been received in the electronic register to allow a translation to be obtained, the fee and routing information is pulsed out via the register relay-set to the register-access relay-set. Following transmission of each routing digit, a test is made by the register relay-set to determine whether a m.f. outgoing line relay-set has been seized. Outgoing line relay-sets associated with m.f. routings are arranged to provide a discriminating signal for a short period following seizure. The discriminating signal is a full earth condition on the positive line, and it is detected by an element within the register relay-set; if no signal is detected, the call proceeds on the normal Strowger basis.

If a m.f. circuit has been seized, the register relay-set forwards a start condition to a digit-store hunter, which drives to find a free auxiliary 6-digit store and its associated m.f. sender and receiver. At the same time, as a consequence of a signal sent to the electronic register, transmission of further Strowger digits is inhibited until association of the m.f. auxiliary equipment has taken place, and the original sending program is altered to provide a "commence-with-D-digit" sequence when sending is resumed. A period of 4 seconds is allowed for association of the auxiliary equipment and this is timed by existing circuits within the electronic equipment.

When association has taken place, the 10-pulse/second loop-disconnect path in the register relay-set is disconnected, and the negative and positive wires outgoing to the access relay-set are switched to the input of the m.f. sender and receiver. On receipt of each transit proceed-to-send signal returned from the registers at successive T.S.C.s, the A, B and C digits stored in the auxiliary code store are marked, via a 2-out-of-5 coding matrix in the 6-digit store, to the m.f. sender and receiver and, subsequently, to the transit register at the T.S.C. In addition, following association of the 6-digit store, a signal is connected to the electronic register to allow sending to continue and the D and subsequent digits are pulsed out, as trains of 10-pulses/second earth-disconnect pulses separated by short i.d.p.s, into the 6-digit store where conversion into 2-out-of-5 form is effected. During this process, the 4-second and 20-second time-out and restraint of sending facilities, which are normally operative on a Strowger-routed call, are inhibited within the electronic equipment and, instead, a 20-40-second time-out is applied following receipt of each digit received in the 6-digit store.

The ensuing transmission of digits to the terminal register at the objective G.S.C., and receipt of number-received or spare-code signals, is similar to that described for the Type 5 equipment.

International Calls Routed via the Trunk Transit Network

International calls are denoted by an A digit of 1 and a B digit of 0 and when the 6-digit store is seized on a transit-

network call, examination is made of the A and B digits stored in the auxiliary code store. If the call is international, a start signal is connected to an allotter circuit which allocates a free 8-digit store. A finder then searches for the 6-digit store initiating the demand. When digits pulsed out from the electronic register have been received on all storage uni-selectors in the 6-digit store, the pulse-repetition path is switched to the 8-digit store where the remaining digits of the international number are stored and converted into 2-out-of-5 form for signalling to the m.f. sender and receiver.

Alternative Routing

At director-area G.S.C.s an overflow method is employed for alternatively routing calls from high-usage Strowger or m.f. routes to fully-provided m.f. routes. A typical arrangement of the outlets of a motor-uniselector-type trunk selector is shown in Fig. 14. If all outgoing relay-sets in the basic high-usage group of circuits are engaged when the last local routing digit is sent, the wipers of the trunk selector are driven to the first free outlet in the fully-provided m.f. group of circuits. Following seizure of the outgoing line relay-set, the m.f. discriminating signal is returned to the calling register and the call proceeds as already described.

Repeat Attempt

The repeat-attempt facility provided on transit-network calls is similar in principle to that described earlier for the Type 2 and Type 3 register-translator equipments, with the exception that the same m.f. sender and receiver is used for both first and second attempts.

Release of Equipment

Clear-down of the register equipment on receipt of number-received, spare-code or congestion signals follows a similar pattern to that described for the Type 2 and Type 3 equipments. Relay CO operates in the register-access relay-set to switch the transmission path through on receipt of a number-received or congestion signal from the outgoing m.f. sender and receiver, and the register and auxiliary equipments are restored to normal. If a spare-code signal is received in the outgoing sender and receiver a signal is connected to the register-access relay-set, which connects N.U. tone to the caller, followed by release of the register and associated equipment.

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- ² BENSON, D. L., and VOGAN, D. H. Controlling Register-Translators, Part 4—Magnetic-Drum Register-Translators. *P.O.E.E.J.*, Vol. 51, p. 291, Jan. 1959.
- ³ TOBIN, W. J. E. The Signalling and Switching Aspects of the Trunk Transit Network. *P.O.E.E.J.*, Vol. 60, p. 165, Oct. 1967.
- ⁴ WALKER, N., STALLWORTHY, F. A., and McLUSKY, R. F. Transit Switching Centres Using BXB1121 Crossbar Equipment, Part 1—Trunking, Facilities and General Operation. *P.O.E.E.J.*, Vol. 60, p. 302, Jan. 1968.

Notes and Comments

Birthday Honours

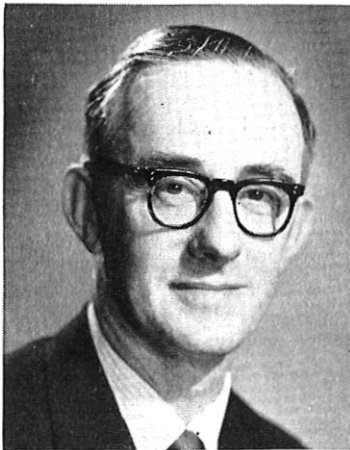
The Board of Editors offers congratulations to the following engineers honoured by Her Majesty the Queen in the Birthday Honours List:

East Area, London	S. H. Brodrick	Inspector	British Empire Medal
Telecommunications Region			
Edinburgh Telephone Area ..	F. M. Holmes	Assistant Executive Engineer	Member of the Most Excellent Order of the British Empire
Guildford Telephone Area ..	C. F. White	Executive Engineer	Member of the Most Excellent Order of the British Empire
South Central Area, London	H. C. Wright	Executive Engineer	Member of the Most Excellent Order of the British Empire
Telecommunications Region			

F. J. M. Laver, B.Sc., C.Eng., F.I.E.E.

The appointment of Murray Laver as Director of the National Data Processing Service continues his long association with data processing, and will be welcomed by his many friends in the Post Office, other Government Departments and in the computer industry.

His particular concern with computers began in July 1956 when he joined the Organization and Efficiency Branch as an Assistant Staff Engineer to take charge of its newly-formed computer group. There followed a period from April 1963 to March 1965 when he was seconded to H.M. Treasury as Assistant Secretary responsible for computer systems in all government departments.



He then moved to the Ministry of Technology to lead the newly-formed Computer Advisory Service, and a few months later became the head of the Computer Division with the rank of C.S.O. The months that followed this appointment saw the new Division involved in hectic activity, and Murray Laver made notable personal contributions to two of the Division's important achievements: the creation of the National Computing Centre, which is now a firmly-established independent body being watched with great interest by computing authorities in other countries, and the rationalization of the British computer industry, which has recently culminated in the formation of International Computers, Ltd.

To his new task as Director of the N.D.P.S., Murray Laver brings a wide range of personal qualities that augurs well for its success.

J. S. W.

F. E. Williams, M.Sc.(Eng.), C.Eng., F.I.E.E.

Francis Williams, recently appointed Staff Engineer in Research Department, was born in Devonshire and educated at Plymouth College. He then went on to Imperial College, London, where, after graduating with a 1st Class B.Sc.(Eng.)

degree, he gained his M.Sc. for research in electro-acoustics. He entered the Post Office as a probationary engineer in 1933, and has spent his whole career in Research Department, mainly on electro-acoustics and sound recording. From 1946 to 1951 he had a spell in charge of the newly-formed postal engineering group, where he initiated work on the single-position letter-sorting machine.



On promotion to Assistant Staff Engineer he then returned to electro-acoustics, bringing his wide experience not only to departmental affairs, but serving on many national and international committees. He has published a number of papers, and has been the secretary of the human-factors research committee almost since its inception in 1964. He brings to the newly-formed Local Telephony and Human Factors Branch not only his unrivalled knowledge, but an infectious enthusiasm and a capacity for disposing of an immense amount of work with the least apparent fuss. His warm and sympathetic personality gain him whole-hearted support from his staff and colleagues.

Among his leisure pursuits, best-known is perhaps his devotion to amateur cinematography, where his skill as producer, director and cameraman has gained him several national awards. The accompanying sound effects are, naturally, always most professionally managed.

E. W. A.

H. T. McGrath, B.Sc.

Over the next year or two, many people will meet Mr. McGrath across the promotion-board table because, on his recent promotion to Staff Engineer, he has been appointed to the Selection Unit of the Telecommunications Personnel Department.

Mac, as he is almost universally known, started his career in the Circuit Laboratory in 1939 and spent much of the early days of the war installing radar equipment around the

country. After obtaining a degree in mathematics and physics in 1948 he was successful in the Executive Engineer's Competition in 1950 and, for the next 7 years, he was involved in the modern development of traffic theory, under A. T. Harmston. During this period he helped to modify and operate the electronic traffic analyser—about which he later wrote an article in this Journal.



On promotion to Senior Executive Engineer in 1957, Mac joined the select band of computer pioneers. He saw the introduction of the two LEAPS computers and the Elliott 803 computer at Dollis Hill, but, having done much of the spade-work involved in planning the Elliott 503 at Gresham Street, he left shortly before it was brought into service, to join the London Telecommunications Region (L.T.R.) on promotion to Regional Engineer. There McGrath spent 1½ years in charge of all maintenance activities in the Region and, later, had a year on exchange design and planning duties.

He thus brings to his new post a broad background of Post Office work and this, coupled with his lively wit and likeable personality, will fit him well for his new responsibilities.

C. A. M.

D. Breary, C.Eng., M.I.E.E.

Denis Breary, recently appointed Staff Engineer in charge of the United Kingdom Trunk Task Force, joined the Post Office as a Youth in 1937. After some years in the London Telecommunications Region (L.T.R.) and Royal Signals he was appointed Probationary Engineer in the Engineering



Department (Equipment Branch), where he was closely associated with a variety of economic and planning projects, including the introduction of S.T.D. He took a special interest in the economics of telecommunications, and in 1963 accepted an I.T.U. appointment as Economic Advisor to the Malayan

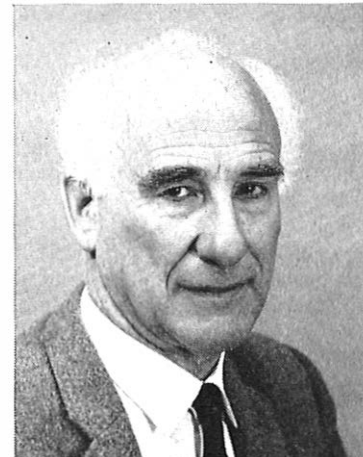
Telecommunications Department. On his return to the Post Office he became a member of the L.T.R. Task Force, and, realizing that electronic computers added a new dimension to planning, was largely responsible for their extensive use in studying the London network. In 1966 he again sought wider horizons and became I.T.U. Regional Expert, African Region. From his headquarters in Ethiopia he visited most parts of Africa, meeting a variety of problems in the field of travel as well as telecommunications. His wide experience of network planning, economics and his ready appreciation of new techniques will be a great asset in his new appointment.

In between his various assignments overseas, Denis has managed to maintain a keen interest in sailing, while his photographic interests have enabled him to keep a personal record of his travels. His friends wish him success in his new task.

H. E. F.

A. W. M. Coombs, Ph.D., B.Sc., A.R.C.S.T.

Those who have heard Dr. A. W. M. Coombs lecture will know of his rare gift for presenting a complex subject in simple terms. This analytical skill, combined with his enthusiasm and technical ability, will stand him in good stead in his new post as Senior Principal Scientific Officer in the Research Department.



Doc. joined the Post Office in 1936 as a Probationary Assistant Engineer (old style), and, after a short time in the Districts, came to Dollis Hill. Here he spent the war years on classified work and, subsequently, as one of the first Principal Scientific Officers in the Department, pioneered in computer technology with the development of "Mosaic."

In 1956 he turned his attention to the application of speech interpolation, and successfully demonstrated the principle in action on the Dollis Hill Open Day of the following year. More recently he has been working on pattern recognition, and he is confident that the techniques which he is developing will make a valuable contribution to postal mechanization.

Doc. of course is a man of many parts, as all who have enjoyed the Dollis Hill pantomimes will be aware. He is a family man who hoped to raise a football team, but settled for four daughters and hockey instead. Amateur theatricals, rugby football and continental holidays are among his many interests. Technically, he likes to make machines do what no machine has done before. We wish him success in a challenging future.

A. J. F.

L. Thomas, C.Eng., M.I.E.E.

Those who came in contact with Leslie Thomas during his formative years knew then that with the gifts of a photographic memory, a capacity for hard work and a fertile imagination he must achieve stardom. His many friends and

colleagues in the Post Office and outside it will be delighted that this has been partly realized by his recent promotion to Staff Engineer in the newly formed Purchasing and Supply Department.

A Youth-in-Training at Swansea in 1939, Thomas laid the corner stone of his career at Criggon Radio Station, and progressed smoothly through microwave system maintenance as Executive Engineer (1949) to the rebuilding of the London-Birmingham 900 MHz link for I.T.V. in 1955. As Senior



Executive Engineer (Main Lines Branch) he was responsible for commissioning cable and microwave links, but these duties were interrupted in 1960 to attend a Joint Services Staff College course. Returning in 1961, he tackled, with complete success, the planning and development work for the North Sea Cable Scheme.

Appointed Assistant Staff Engineer (1964) in the External Telecommunications Executive, Thomas was soon immersed in the, as yet, unfinished task of planning and maintaining the rapidly growing international cable and satellite network.

Leslie Thomas is one of the most enigmatic of engineers for he combines a natural talent for organization and planning with a deep-rooted kindness and understanding of people. He is never deflected from policies he believes to be right in spite of the inevitable pressures which are part of official life. These are qualities which will be of inestimable value in his new assignment.

W. H. L.

M. Mitchell, M.B.E., E.R.D., B.Sc.(Eng.), C.Eng., M.I.E.E.

Three recurring elements can be detected in the career of Maurice Mitchell, now responsible for engineering training in succession to R. O. Boocock.

The first of these is training: 2 years from 1934 as a Youth-in-Training in the old E.-in-C.'s Training School, Dollis Hill; 3 years from 1946 as an Executive Engineer at Stone, on transmission and engineering management courses; then, 2 years from 1949 as Regional Training Officer, London Telecommunications Region, responsible for training methods and techniques over all operational fields.

The second element is the Circuit Laboratory, where he served from 1936 to 1946 (excepting the war years), and then as Senior Executive Engineer from 1951 to 1955, during which the Laboratory was transferred to Armour House and re-organized.

The third element is military activities: school O.T.C., Supplementary Reserve, and then war service in the Royal Signals where he progressed from 2nd-Lt. to Lt.-Col.

In 1955 he was loaned to the Ministry of Defence as Controller, Telecommunications Group, B.A.O.R., responsible for liaison between the German Federal Post Office and B.A.O.R., and for the operation of B.A.O.R.'s static tele-

communications. Returning to the Post Office last year, he has been responsible for graduate recruitment and liaison with Universities.

Educated at University College School and by evening study at Northampton Polytechnic (1st Class Honours degree



and the award of the Walmesley Memorial Prize), Mitchell has qualities of tact and friendliness which, combined with a good memory and gentle persistence, will help him to meet with success the challenge of the changing requirements of engineering training and its organization that will arise as the new Post Office (Telecommunications) speeds on its way.

T. F. A. U.

S. G. Young, B.Sc.(Eng.), C.Eng., M.I.E.E.

Stanley Young's many friends are gratified to learn of his recent appointment as Staff Engineer to lead the new Postal Engineering Research and Advanced Development Branch, Postal Headquarters. Joining as a Probationary Executive Engineer in October 1947, he took up duties involving a knowledge of structures, radio-frequency power distribution and switching, aerial design and transmitter cooling systems, to name only a few aspects. After 15 years in this field (he was promoted to Senior Executive Engineer in 1957), many of the techniques now accepted as standard practice bear witness to his energy and initiative.



Promotion to Assistant Staff Engineer (1962) widened his interests further, and he was, for a time, Chairman of C.C.I.R. National Study Group III. A transfer in February 1963 brought him into contact with the procurement and maintenance of microwave radio-relay systems during a time of particularly vigorous expansion and technological development covering the growth of the broadband network from

6,000 to 18,000 channel miles, and the inauguration of the Post Office Tower and the Birmingham Tower, the first commercial 1,800-channel system, the first colour television transmission system, and the first all-solid-state repeater and multi-band horn aerials.

Mr. Young can be counted on to accept the challenge offered by the new post to his undoubted versatility with customary enthusiasm. His new colleagues will discover that his special brand of good humoured, if sometimes provocative, ebullience is a cloak for a shrewd intellect and an abiding sense of human values. The many friends he leaves behind will miss his cheerful companionship and wish him every success in his new sphere.

D. W. C.

A. C. Croisdale, M.B.E., B.Sc.(Eng.), C.Eng., M.I.E.E.

Mr. A. C. Croisdale, recently appointed Staff Engineer, Civil and Mechanical Engineering Branch, Telecommunications Development Department, entered the Post Office as a Probationary Inspector in 1937 after 4 years as an apprentice draughtsman. Following training, he was posted to the External Plant and Protection (Cn) Branch and worked on the protection of telecommunications plant from the effects of power lines.

After war service he returned to the Post Office in 1946, and, continuing his private studies, obtained his degree in electrical engineering and passed the Limited Competition for Executive Engineer.

Promoted to Senior Executive Engineer (1953) in Telegraph Branch he worked on automatic error correction for radio-telegraph circuits, soon becoming an expert and representing the Post Office at both the C.C.I.T.T. and C.C.I.R.: he gained a high reputation internationally and his many published articles are somewhat of a textbook on this subject.

In 1963 Croisdale was appointed Chief Factories Engineer.

This extraordinary change of job provided extremely valuable experience of work study, inspection methods, flow-line planning, training and management, and on his return to Cn Branch as Assistant Staff Engineer (1965) the experience proved invaluable in introducing new productivity methods into external construction.



Alan Croisdale follows a long line of distinguished Heads of the former "Construction Branch": I am certain he will maintain their high standards. The view has been expressed that the talents of an expert on telegraph error correction are wasted on mere mechanical engineering—Alan Croisdale's talents will not be wasted anywhere, and I am sure the Civil and Mechanical Engineering Branch will go from strength to strength under his leadership.

E. C. S.

Institution of Post Office Electrical Engineers

Retired Members

The following members, who retired during 1967, have retained their membership of the Institution under Rule 11(a):

- D. A. Barron, C.B.E., 18 Ruddons Road, Beckenham, Kent.
- J. W. Freebody, 271 London Road, Ewell, Surrey.
- F. Hollinghurst, 49 Granville Road, Barnet, Herts.
- W. A. J. C. Ongley, 5 Linden Court, Leatherhead, Surrey.
- Major J. H. Russell, T.D., 3 Moorfoot Avenue, Thornliebank, Renfrewshire, Scotland.
- A. K. Robinson, 40 Nursery Lane, Leeds 17, Yorkshire.
- A. W. Hall, 47 Horn Park Lane, Lee, London, S.E.12.
- J. W. Barratt, 20 Hastingon Drive, Bradford 9, Yorkshire.
- W. J. Paul, 54 Norfolk Avenue, Palmers Green, London, N.13.
- S. A. Norris, Lovelace Drive, Pyrford, Nr. Woking, Surrey.
- F. S. Wallington, 71 Gt. Brockeridge, Westbury-on-Trym, Bristol.
- A. W. Evans, 18 Long Meadows, Bramhope, Nr. Leeds, Yorkshire.
- H. Knee, 53 Harnham Road, Salisbury, Wiltshire.
- J. Smith, 30 Christchurch Avenue, Kenton, Harrow, Middlesex.
- R. Welburn, 24 Hilltop Road, Earley, Reading, Berks.
- L. F. Scantlebury, O.B.E., 19 Hirst Hill, Lilliput, Parkstone, Dorset.

Institution Field Medal Awards, 1966-67 Session

In addition to the Institution Senior and Junior silver and bronze medals, the Field Medals are awarded annually for the best papers read at meetings of the Institution on field subjects primarily of Regional interest.

Field Medals were awarded to the following authors for papers read during the 1966-67 session:

- A. Ness, Telecommunications Headquarters, Scotland. "The Elements of Automatic Control as Applied to a Large Central-Heating Installation."
- W. Sheldon, Telecommunications Headquarters, Scotland. "A Review of Post Office A.C. Signalling Systems."
- E. G. Clayton, Telephone House, Norwich. "Norwich Telephones—The Early Days."

Result of the Essay Competition, 1967-68

A prize of £6 6s. and an Institution Certificate have been awarded to the following competitor in respect of the essay named:

- I. M. Hogg, Technical Officer, Aberdeen. "Maintenance of Custom Service in a Growing Telephone Network."

Prizes of £3 3s. each and Institution Certificates have been awarded to the following four competitors:

- M. J. Johnson, Technician IIA, Newcastle. "Production and Evaluation of Highly-Reliable Silicon Planar Transistors."
- P. J. Povey, Technical Officer, Taunton. "A Short History of the Pneumatic Telegraph."
- J. Morrison, Technical Officer, Dundee. "A Layman's Introduction to Pulse-Code Modulation."
- R. J. Spring, Technical Officer, Birmingham. "More Efficient Use of Manpower in an Automatic Exchange."

Institution Certificates of Merit have been awarded to the following five competitors:

- D. E. G. Coles, Technical Officer, Birmingham. "A Disciplined Approach to Circuit Provision Based upon the Critical-Path Method."
- J. J. Webster, Technical Officer, Edinburgh. "Micro-electronics."

M. J. Boomer, Technician IIA, Newcastle. "Pulse-Code Modulation and its Application to Telephony."

A. J. Fryatt, Trainee Technician, Ipswich. "Some Developments in Management Techniques since the Industrial Revolution."

J. G. Wardle, Technical Officer, Birmingham. "The Origin and Evolution of the Universe."

The Council of the Institution records its appreciation to Messrs. W. A. Humphries, T. Nicholson and R. Holden, who kindly undertook to adjudicate upon the essays entered for the competition.

N.B.—Particulars of the next competition, entry for which closes on 15 January 1969, will be published later.

Nuffield Talking Book Library for the Blind

The above organization has asked the Institution to publicize its appeal for volunteers to help service tape reproducer equipment in blind persons' homes. Post Office technical staff, by virtue of their knowledge and experience in this and allied fields, are clearly well suited for this work. The machines are basically simple amplifiers, and full circuit diagrams and guidance notes would be provided.

Volunteers are required throughout the country, and it is understood that a central organization would contact a volunteer nearest the home of a blind person reporting a fault or asking for help. The areas in which help is particularly urgently required are as follows.

London: N.8, E.2, E.10, S.E.1, S.E.3, S.E.5, S.E.8, S.E.10, S.E.11, S.E.12, S.E.16, S.E.17, S.W.1, S.W.11, N.W.6, N.W.8, N.W.10 and N.W.11.

Cornwall: Port Isaac.

Caernarvonshire: Pwllheli.

Durham: Bishop Auckland.

Essex: Dagenham.

Gloucestershire: Lydney.

Lancashire: Garstang, Kirkby, Morecombe, Warrington.

Lincolnshire: Grantham, Market Rasen.

Merionethshire.

Nottinghamshire: Bottesford.

Staffordshire: Leek.

Suffolk: Aldeburgh, Leison, Saxmundham.

Yorkshire: Barnsley, Kexborough.

Post Office staff willing to assist in this work, or requiring further information, should apply to D. Finlay-Maxwell, Esq., M.I.E.E., Talking Books for the Blind, c/o John Gladstone & Co., Ltd., Wellington Mills, Huddersfield, in the first instance, who will supply all details.

It will be appreciated that neither the Post Office nor the Institution undertakes any responsibility in this matter, and that all arrangements are between the volunteer and the Nuffield Talking Book Library organization.

A. B. WHERRY,
General Secretary.

Additions to the Library

Library requisition forms are available from Honorary Local Secretaries, from Associate Section Centre Secretaries and representatives, and from the Librarian, I.P.O.E.E., G.P.O., 2-12 Gresham Street, London, E.C.2.

Members are reminded that Prize Essays, Associate Section Prize Papers, and various unpublished papers are held in the library for loan, and that a list will be sent on request. Field Medal award-winning papers are also held for loan and are listed in the Supplement to the Library Catalogue.

2942 *101 Questions and Answers about Transistors*. L. G. Sands (Amer. 1966).

The questions contained in this book are the ones most often asked. The answers are simplified and illustrated with schematic diagrams, graphs and photographs.

2943 *Electronic Inverters*. F. G. Spreadbury (Brit. 1967).

All types of inverters currently employed are described

and some account is given of applications and future d.c. energy sources.

2944 *High Frequency Communications*. J. A. Betts (Brit. 1967).

Short and simply written, so that it may be read in a few days by anyone with the general background of a second-year student. The text is supported by references most likely to help the reader who may wish to pursue the subject, or some part of it, in greater depth.

2945 *Plastics for Engineers—An Introductory Course*. G. R. Palin (Brit. 1967).

Intended primarily for students in all fields of engineering and for qualified engineers who require a simple introduction to the subject.

2946 *Understanding Telemetry Circuits*. J. D. Lenk (Amer. 1966).

For those, either servicing the equipment or requiring a basic knowledge and understanding of the various telemetry techniques in use today.

2947 *Large Signal Transistor Circuits*. D. T. Comer (Amer. 1967).

Completely covers device physics and equivalent circuits, providing a thorough basis for the study of practical circuits.

2948 *Communication System Engineering Handbook*. D. H. Hamsher (Amer. 1967).

Contributions by experts in every aspect of communications give an informed overview and appraisal of the entire field. A comprehensive handbook with five major sections covering fundamental design considerations, system engineering, circuit engineering, engineering and construction of facilities, and scientific fundamentals, e.g. switching, noise, coding and acoustical theory. All methods of communication and transmission are thoroughly treated.

2949 *Techniques of Pulse Code Modulation in Communication Networks*. G. C. Hartley, P. Mornet, F. Ralph and D. J. Tarran (Brit. 1967).

Surveys the potentialities of pulse-code modulation and the issues involved in its adoption in communication networks. It is aimed at the practising engineer and the graduate student seeking to broaden his knowledge of the technique.

2950 *Understanding Computers*. T. H. Crowley (Amer. 1967).

Will help the non-technical reader to understand how modern digital computers operate, what they can and cannot do, and how they are affecting society today.

2951 *Thin-Film and Semiconductor Integrated Circuitry*. J. Doyle (Amer. 1966).

Provides comprehensive coverage of the many disciplines involved in the fabrication of thin-film and integrated circuits. The book focuses on the general problems associated with integrated circuits and the techniques used to solve them. Will be equally useful to the student and the practising engineer.

2952 *Introduction to Computers for Engineers*. M. P. Moyle (Amer. 1967).

Primarily written as a "first reader," but contains sufficient supplementary material to make it useful to those with some experience in this field.

2953 *Car Maintenance and Repair (Sixth Edition)*. A. W. Judge (Brit. 1967).

This edition has been brought up-to-date to include more recent cars, but since it is older models which are most in need of attention some earlier servicing and maintenance has been retained. Special consideration has been given to the servicing of cars so that they will pass official tests.

2954 *Advanced Electrical Technology*. H. Cotton (Brit. 1967).

A comprehensive text for second-year and final-year students of electrical engineering.

2955 *Principles of Electrical Technology*. H. Cotton (Brit. 1967).

A first-class book for first-year electrical engineering students which will also be of considerable value to Higher National Certificate students.

E. DOHERTY,
Librarian.

Regional Notes

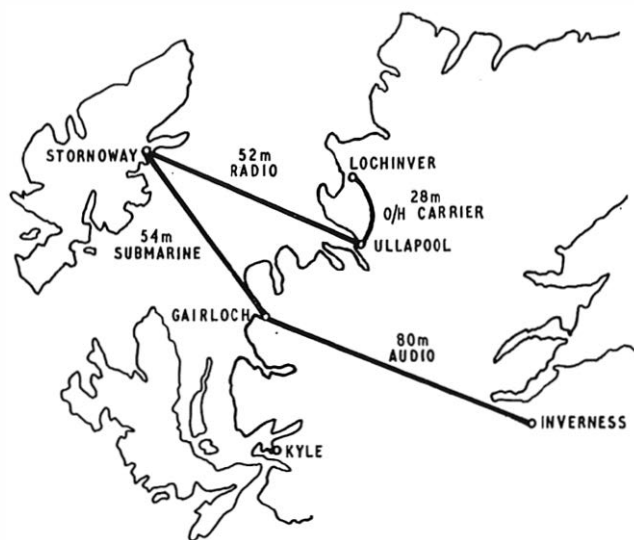
Scotland

A Long Way Round?

The issue of a Circuit Completion Report (A175) is not usually an occasion which promotes excitement. However, the provision of three public traffic circuits from the picturesque north-west of Scotland fishing village of Lochinver to the Highland Capital of Inverness, was just such an occasion.

The existing traffic route on two overhead carrier systems in tandem, with no spare capacity, was experiencing severe congestion. Scrutiny of line-plant records by the Area Circuit Provision Control produced a novel solution, utilizing spare line plant.

The co-operation of Telecommunications Development Department, Oswestry, was sought to assign cable pairs from Inverness to Gairloch repeater station—the U.K. Scotice terminal—in a section of 80 miles of loaded audio cable, 25 miles of which is aerial cable. Routing to Stornoway in the Outer Hebrides, is on submarine carrier cable across the stormy Minch. Recrossing of the Minch to Ullapool is on a radio-routed carrier channel. The last lap to Lochinver is completed on a modern transistor-type, overhead carrier system as shown in the map.



Route taken by the new circuit

After a successful initial trial, three Inverness–Lochinver trunks were provided to relieve congestion. This method of relief was adopted in advance of the Highlands and Islands relief scheme which is not due in the Lochinver area until 1970–71.

The existing route mileage of the overhead carriers between Inverness and Lochinver is 87 miles. The new circuits, however, are 215 miles long, and of good quality and performance.

J. D.

Northern Ireland

Bridging the Gap

A new telephone exchange is being built in Belfast to cater for local requirements in the centre area. The exchange, appropriately named City, has been planned to have a cable lead-in at each end of the cable chamber with 96 bores at the north end and 48 bores at the other entrance. Immediately following the piling of the site and completion of the basement the provision of the underground lead-in arrangements were scheduled for completion. This sequence of operations enables external cabling work to proceed concurrently with the construction of the building.

Severe disruption of traffic could have occurred during the provision of the lead-in to the north end of the building because the duct track crosses a four-lane highway, and it was necessary to provide a carriage-way manhole giving access from the grass

verge after the completion of a planned dual carriageway. The depth of excavation for the manhole had to be approximately 18 feet but, because of the restricted main road, was unacceptable for safety reasons. A complete road closure was contemplated and with difficulty could have been implemented. However, the army were consulted and it was found that, with the provision of a heavy girder bridge, two-lane traffic could be maintained during the underground operations.

The road was closed to traffic from midnight on a Saturday, and this enabled the portion of the excavation which would be under the bridge to be well advanced. Preliminary investigations had shown that the ramps to the bridge would require to have an incline of 1 in 13 in order that the local authority "Fleetline" buses under full-load conditions would not strike the ramp. Special arrangements in the form of additional asphalt ramps were provided and one of these



The girder bridge over the work

ramps can be seen in the photograph. A local unit of the Territorial Army Volunteer Reserve erected the bridge in 6 hours, and the road was opened for two-lane traffic on the Sunday evening. The underground ducts and manhole were completed in 5 weeks with the bridge in position. On the following Sunday, with the road closed for 13 hours, the army recovered the bridge and the road was reinstated before being restored to normal four-lane traffic.

This scheme avoided the necessity of a complete closure of a busy city artery for a period of 5 weeks, which would have caused serious traffic congestion and considerable inconvenience to the travelling public.

W. G.

North Western Region

Storm Damage in Lancaster Area

Only eight months after the severe flooding in the southern part of Lancaster Area, exceptionally heavy rainfall over east Cumberland and Westmorland on the night of 23–24 March 1968 resulted in a very high water level in the River Eden, such that flooding in the river valley was widespread. Many dwellings at Appleby and Carlisle had to be evacuated temporarily. The floods are shown in the photographs.

Damage to Post Office plant in the Appleby district was relatively minor. Eleven miles down river at Langwathby a two-arched bridge, 300 years old, carrying the Alston–Penrith A686 road was demolished by the swollen river. Operation of the cable-pressure alarms on the Langwathby cable at 5.25 a.m. on 24 March was the first indication that something was seriously amiss. Enquiries revealed that the Penrith–Langwathby junction cable and local cables had been swept away with the bridge, isolating Langwathby U.A.X. By 3.50 p.m. one temporary circuit to Penrith had been provided by stringing cable drop-wire to hedges and trees over the flooded countryside to Culgaith U.A.X. and thence utilizing spare pairs in the junction cable to Penrith. An



The floods of the River Eden

additional circuit provided by similar means was in service by 6.10 p.m. In the meantime restoration of the severed junction cable to Langwathby was proceeding. The major difficulty in this operation was to provide the initial draw-rope across the swollen river, now 80 yards wide and flowing at 15 knots. Police and local utilities were unable to assist, but eventually a local Cumberland ex-champion archer, the father of a local Post Office employee, succeeded in "shooting" a nylon fishing line across the river. Progressively heavier draw-ropes were then hauled across the river and finally an aerial interruption cable was erected. Full junction service to Langwathby was restored at 11 p.m. on 24 March. The P.M.G., the Rt. Hon. Edward Short, M.P., was a witness of the roping and cabling operations, and congratulated the local staff and the archer on their resourcefulness.

At Carlisle the first hint of serious trouble came at 9.30 a.m. on 24 March when a report was received that the vehicle park at Willowholme was flooded. Forty-two maintenance and installation vehicles stood in 4 feet of water. A reconnaissance was made by boat to determine the possibility of recovery of the vehicles but the depth of water and current were so great that it was decided the recovery attempt should be deferred until low tide around 2 p.m. Recovery of the vehicles began at 2 p.m. and was completed by 7 p.m. when all 42 vehicles were under the care of the Workshop Supervisor. The following day drivers had a busy time cleaning out vehicles, disposing of damaged stores and apparatus, and replenishing stocks.

Considering the extent of the flooding, cable damage in Carlisle was moderate, thanks to cable pressurization. Two cabinets were flooded to a depth of 18 in. A cabinet at Willowholme had 400 E-side pairs and 800 D-side pairs affected. The principal worry here was the complete line-isolation of the Cumberland Infirmary. Communication was maintained by mobile police radio until 2 p.m. on 24 March, by which time line circuits had been restored by intercepting spare

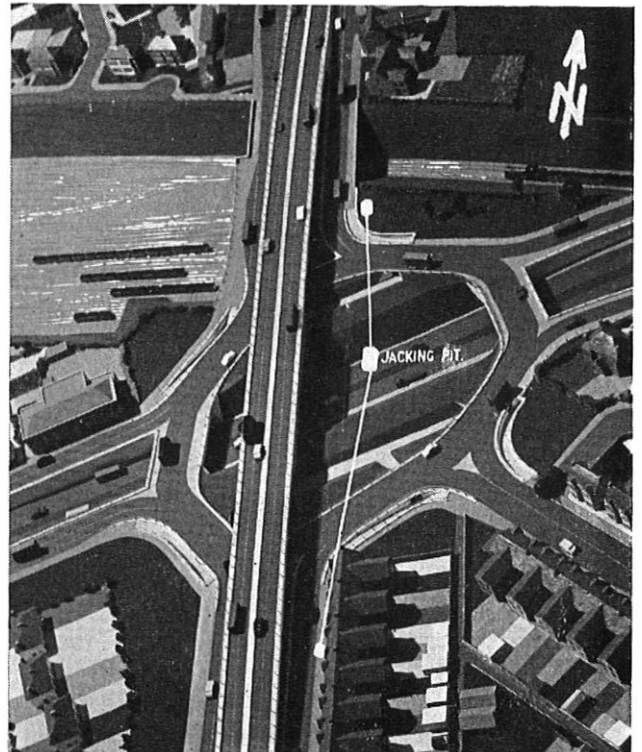
pairs in the Burgh-by-Sands-Carlisle junction cable which passes the Infirmary entrance. Temporary clearance of faulty pairs was completed by the afternoon of 27 March. A cabinet in Warwick Road had 200 D-side pairs affected and faulty pairs were cleared by the evening of 25 March. Numerous faults on small distribution cables were all cleared by the early morning of 26 March 1968.

J. M. and J. E. P.

Wales and Border Counties

Pipe Jacking at Roadworks in Cardiff

At the junction of several existing main roads and a proposed inner by-pass road, a large three-level interchange is being constructed by Cardiff City Council under the auspices of the Welsh Office. The by-pass will run through the interchange at the lowest level, some 24 ft below existing ground level. The photograph shows part of a model con-



Position of jacking pit in the roadwork scheme

structed by the Cardiff City Council Planning Authority and shows the scale of the work but not necessarily the detail of the final design.

The problem presented to the Post Office was one frequently met on roadwork schemes. Multiple-way ducts and cables crossing the site had to be temporarily or permanently replaced in a different position so that the road works could proceed. Seventeen duct ways, about 160 yd long and carrying MU and CJ cables (including television coaxial cables) and local-exchange cables, had to be re-routed.

Consideration was given to two possible schemes. The first was to span the site with interruption cables carried on two pylons. New duct would then have been laid in conjunction with the road works, and permanent cables drawn in and changed over, and the interruption cable and pylons recovered. The alternative was to drive a tunnel between two large manholes, one on each side of the site, linking existing duct-lines, install ducts in the tunnel, and draw in permanent cable.

The pylon scheme would have been costly, and the cables would have been vulnerable for perhaps two years. This scheme was discarded.

The tunnel scheme appeared to be the answer, but because of the depth required to pass under the proposed inner by-pass the tunnel had either to be constructed between very deep-shafted manholes, or with a dip to a lowest point and a rise to

normal depth at the far end. Each variation of this scheme had its drawbacks, and, at this stage, pipe jacking was suggested as opposed to usual tunnelling methods. Since pipes can only be thrust in a straight line it seemed that deep shafts were needed. Finally, it was decided to sink a shaft at the lowest point of the interchange, and from there to thrust pipes upwards and outwards towards terminating manholes on each side. The position of the jacking pit is shown in the photograph. In these particular circumstances pipe jacking was more economical than conventional tunnelling. The position of the jacking pit was critical, and the only site available was the front garden of a vicarage. This position was almost ideal since it was not only close to the required line of pipe but also off the highway at a busy traffic junction.

The specification for the work covered the provision of a 42 in. diameter concrete pipe and the installation of 70 p.v.c. ducts in the concrete pipe, the spigots and sockets being coated with an approved adhesive. A 42 in. pipe was the minimum that could be considered since a man had to carry out all the excavation, working inside the pipe.

Tenders were invited and the contract was awarded to a firm of mining and tunnelling engineers in September 1967. The basic dimensions of the scheme are as follows.

Total length of pipe-jacked section	156 yd
Distance from jacking pit to south end	94 yd
(Gradient 1 in 7·8)	
Distance from jacking pit to north end	62 yd
(Gradient 1 in 5·2)	
Jacking-pit dimensions at top	25 ft ²
Jacking-pit dimensions at bottom	20 ft ²
Jacking-pit depth	46 ft
Change of direction of pipe at the jacking pit	
in the vertical plane	18°
in the horizontal plane	11°

Soil-survey reports were supplied by the Council from several boreholes made in the area down to 50 ft, which showed strata subsoil varying from sand to clay, gravel, cobbles, red marl, boulder clay, but no rock. Water was expected but not in unmanageable quantities. The line of thrust would cut through various strata in turn, each presenting its own difficulties.

The jacking pit was excavated to the required depth, water being the chief problem encountered. A rough concrete floor was laid at the bottom of the pit and a reinforced concrete wall constructed at the south side of the pit in readiness for

jacking the 62 yd section towards the north. Having set the thrust line, jacking then progressed smoothly on continuous shift work and the general rate of progress was two pipes per day. Prior to thrusting, each pipe was coated with lubricant. The south-side thrust wall was then demolished and a similar wall built on the north side so that jacking could proceed in the other direction. At the completion of this thrust the north-side thrust wall was demolished. The second photograph shows pipes being installed.

The biggest difficulty in the jacking and excavating work came when the sand strata was encountered, and the cutting shield had to be enlarged to give protection to the digger. No intermediate jacking stations were needed other than those at the front of the pipe which were necessary to correct line and level.

The next task was to install the p.v.c. ducts in the concrete pipe. Although 70 ducts did not fill the pipe this number was calculated to be more than adequate for as far as can be foreseen. Duct No. 54, thick-walled p.v.c., was chosen because of its good self-supporting properties under load, i.e. it will not distort under full cable load when laid up in natural contact with the other ducts in the nest, and does not require cement grouting or some other fill in the interstices between the ducts. Before the duct was installed close attention was paid to the accuracy of curvature of the concrete bed in the jacking pit.

The ducts were installed singly from the reception pit at the north end and pushed through the entire 156 yd length by hand. This required three men at the north end engaged in jointing and pushing the pipes, and two men giving help in the jacking pit. The job was done quickly and easily, and the duct formation was satisfactorily controlled. By chance it was found that water is an excellent lubricant. The 70 pipes were installed in three days.

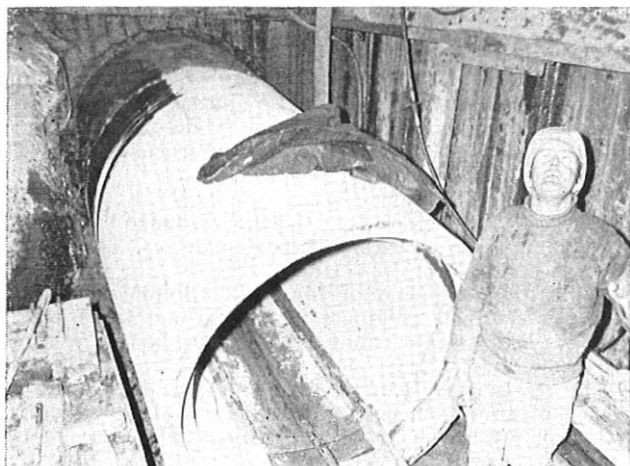
In the jacking pit the ducts were banded together and encased in reinforced concrete. The reinforcing was so designed as to overlap the concrete pipes, thus making this section an integral part of the whole. On completion all ducts were tested using the pneumatic rodding device and were carefully numbered. Extreme care had to be exercised during the rodding operation since the projectile emerged with an impressive velocity. A field telephone was set up to improve safety conditions.

The jacking pit was backfilled in 2 ft lifts using lean-mix concrete for the first few feet and then quarry top strip-pings well compacted up to existing ground level. Pulverized fuel ash (p.f.a.) had been stipulated by the Council for fill up to the new road level because of its excellent compaction qualities, but in this case p.f.a. proved unsatisfactory because the rapid inflow of water turned it into a slurry.

The 70 p.v.c. ducts will terminate in large non-standard manholes where they will be linked to more conventional multiple-way ducts. The bottom layer of p.v.c. ducts will not be cabled so that periodic ovality tests can be made as the cable load increases over the years. The ducts will be sealed in the manholes to keep out water and silt which could accumulate at the lowest point and block the pipes.

The project, completed in just over four months, has shown the usefulness of the pipe-thrusting technique, and the ease with which p.v.c. duct in long lengths can be handled, but this question now arises . . . could the p.v.c. ducts be dispensed with in future jobs of this kind?

Throughout the project Cardiff Corporation provided every facility for the smooth running of operations including such matters as preliminary planning, checking the civil-engineering aspects of the work, arranging for disposal of spoil and acquisition of backfill material, and their assistance is gratefully acknowledged.



Jacking pit showing pipes being installed

W. H. D. and J. H. N.

Associate Centre Notes

Exeter Centre

At the annual general meeting on Thursday 25 April the following officers and committee were elected: *President*: Mr. W. J. Foster; *Chairman*: Mr. G. S. Steer; *Vice Chairman*: Mr. L. E. Hines; *Hon. Secretary*: Mr. T. F. Kinnaid; *Hon. Assistant Secretary*: Mr. J. J. F. Anning; *Librarian*: Mr. N. H. B. West; *Auditors*: Messrs. B. Adams and P. Hartnell; *Committee*: Messrs. M. Durrant, D. Elford, S. G. Page, J. Petherick and M. Saunders.

Members will doubtless notice many new names here. The Presidency changes as a matter of routine and we welcome our new President, Mr. W. J. Foster, who together with the new Chairman and Vice Chairman has for many years taken a very active interest in the Centre. We all hope that under the guidance of this new team the Centre will continue to flourish as it has so successfully done since re-formation in 1962.

We owe a great deal to all those retiring, namely, Mr. E. H. K. Brown (President), Mr. R. Powlesland (Chairman), Mr. P. James (Vice Chairman), Mr. G. A. Srodzinski (Librarian), Messrs. G. A. B. Sealey and J. L. Summers (Committee members), and to Messrs. G. E. Hall and D. J. Hitchcock (Auditors).

The average attendance at last winter's meetings was 46. This is approximately 15 per cent of the membership, and quite satisfying. We would, however, very much like to see an increase in our membership. At the moment our membership is about 50 per cent of those eligible to join the Centre. This could be improved, particularly by the external staff.

The last three papers of the winter proved to be the most popular. At the January meeting, Messrs. K. W. Hix and C. E. A. Orridge presented their paper "Fault Location in Telephone Exchange Networks." While the paper proved to be too long for the time allowed, members very much appreciated the evening and we hope Mr. Orridge will return next winter to present another paper devoted to Strowger equipment maintenance.

The Associate Centre T.T.A. Award was also presented at this meeting to Mr. P. Osborne by the President, Mr. E. H. K. Brown.

The February meeting was addressed by Mr. J. H. Brock, Manager of Lloyds Bank, Exeter. Mr. Brock proved to be an excellent speaker who made an interesting and amusing evening of what is generally thought to be a dull subject.

Our last meeting was a talk by our almost regular speaker Mr. G. F. Cload. His subject, "Canals," was quite absorbing—it is difficult to find fresh adjectives when commenting on Mr. Cload's utterances; suffice to say that anyone who has heard Mr. Cload will accept that his talk this time was as good as ever.

We will soon be involved in the preparation of next winter's program and should members have any comments or suggestions to make, perhaps they would contact any officer or committee member. Your help in this will be greatly appreciated.

T. F. K.

Plymouth Centre

A successful winter session was brought to a close with a visit to the satellite tracking station at Goonhilly Downs on Saturday 6 April 1968. The visit was greatly appreciated by the members.

During the latter part of the session we have had a visit to the local police headquarters where members were given a lecture entitled "Modern Crime Detection." A paper was also presented by Messrs. Hix and Orridge entitled "Fault Location in Telephone Exchange Networks." Both of these proved highly interesting and informative.

J. B. L.

Stoke-on-Trent Centre

The annual general meeting took place with Mr. J. A. Hart as Chairman on 10 April 1968.

In 1967-68 attendances were not as satisfactory as in the previous year despite a program which had attracted com-

mendation. The formal meetings were "The Area Board," "Pulse-Code Modulation," by Mr. G. H. Bennett, "Promotion Procedure," by the Telephone Manager, "London G.P.O. Tower," by Mr. W. L. Newman, and a "Triangular Quiz" between the group switching centres—an event won by the Crewe members.

In the preparation of these events the Committee were grateful for the assistance given by the Centres at Manchester, Reading and the Central Training School. The Committee were also indebted to the Board who continued to provide generous support and encouragement for the Centre.

Membership remained stable during the session despite more promotions to the executive grade. These advancements included the names of our Vice-Chairman, Mr. A. E. Fisher, and the Stafford representative, Mr. R. Sutton.

In 1967-68 we also lost the services of Mr. Bill Roberts, who resigned owing to ill-health. The Chairman, in his report, paid tribute to the committee work of these officers, and welcomed their successors, Messrs. Parton, Yates and Whieldon.

In his review of the session, the President also drew attention to the question of attendances. He said that members had much to gain from the meetings, particularly the younger officers.

The following officers were elected to serve the Centre for the 1968-69 session: *President*: Mr. K. Gray; *Chairman*: Mr. J. A. Hart; *Vice-Chairman*: Mr. C. Winfield; *Secretary*: Mr. S. P. Hancock; *Assistant Secretary*: Mr. K. T. Bevington; *Treasurer*: Mr. E. A. Hudson; *Librarian*: Mr. E. J. Foden; *Committee*: Messrs. Parton, Yates and Whieldon; *Auditors*: Messrs. Yates and Colclough.

S. P. H.

London Centre

London Centre had a truly tremendous audience for their February lecture entitled "Pulse-Code Modulation." The number swelled to nearly 250 and all were impressed by the lecturer, Mr. Jarvis, and by the items of equipment and displays that he had brought along.

For the March talk a return was made to the subject of colour television and this time the lecturer, Mr. Clinch, concentrated on the PAL system that has been adopted in this country. Apart from describing the differences and similarities with the other systems he discussed some of the difficulties that had been experienced since transmissions commenced. Once again the audience was large in number and suitably entertained with demonstrations.

The last lecture in the 1967-68 session was called "TXE6" and was given by Mr. Peacock. He and his colleague, Mr. Probert, talked on the system which was described in some detail in this Journal, in January 1968. Particular reference was made to the field trial at Belgravia.

Two visits were arranged last session by Mr. K. Lister: to Guest, Keen and Nettlefolds at Smethwick, and to the Greenwich Observatory at Herstmonceux in Sussex. Both were quite successful.

Under the Editorship of Mr. B. E. Bolton the "New Quarterly Journal" continues to flourish and win friends. With it London Centre contrives to serve the best interests of the membership.

The reorganization of the London Areas has caused a degree of disruption, and activities among the local areas have been somewhat curtailed. One or two areas were without full management committees but, nevertheless, London Centre looks forward to the coming session with justified optimism. Among the program items for 1968-69 is the much publicized visit to America run by N.W. Area and a lecture to be given by the new President of the Associate Section, Dr. P. R. Bray.

B. E. B.

Aberdeen Centre

On 14 February, Mr. Ferguson the Planning Area Engineer gave a talk entitled "The Aberdeen Area—The Next Five Years." In his talk he detailed some projects necessary for

the introduction of S.T.D. into the Highlands and Islands scheme.

On 6 March we picked one of the few good days in the month for a visit to the Pulp Mill at Corpach, Fort William. There we saw the complete process of converting timber from Scottish forests into pulp and then into paper.

Mr. Birss, our Liaison Officer, retired from duty on 1 March. We wish him a long and happy retirement.

R. M.

Ayr Centre

The present session of the Centre began with a visit to Busby Spinning Mills, Kilwinning, in October. From the storage sheds containing the raw wool, both home and imported, the various blinding, carding and spinning processes were followed through to the finished product in the form of spun yarn. In this factory, some of the original machinery installed in the 19th century was still working satisfactorily adjacent to the most modern nylon-spinning equipment. In November, a talk was given by Mr. C. Cowan of the Scottish Region on "Cable Pressurization." In addition to his very informative talk Mr. Cowan had a compressor-desiccator on view together with many other items of pressurization equipment. Due to local circumstances it was not found possible to organize the proposed visit to Scottish Aviation, Prestwick, in January but this visit will be held over until the forthcoming session. In February one of our members, Mr. H. Mason, gave us a talk illustrated by slides entitled "The Lean and the Hardy" concerning the lives and activities of the rural communities in the South West. The March meeting consisted of a talk, illustrated by slides, on the subject "Statistics and Probability," by Mr. D. Soutar, Area Engineer. Our speaker by relating his subject to all aspects of life, not necessarily Post Office activities, gave us a very interesting talk and a lively question session followed.

A. B.

Dundee Centre

Our visit to the Scottish Pulp and Paper Mills at Fort William on 5 April concluded an excellent programme for the 1967-68 Session.

The Associate Section was host to a galaxy of four speakers from London: Dr. Coombes on "Patterns Recognition," Mr. L. J. Bolton on "P.C.M.," Mr. P. Skinner on "Crossbar Exchanges" and Mr. D. E. Kennard on "P.O. Cable Ships at Work."

The home contributions came from Mr. D. H. Cook on "Photography—Simple Processing," Mr. F. B. Soutar on "Stamp Collecting" and Mrs. D. Lawden on "Expo '67."

The annual general meeting was on 7 May 1968.

The Committee wishes to express its thanks to all who came along to the meetings and made them a great success.

Now that the habit has been formed, we look forward to even greater things next session.

R. T. L.

Edinburgh Centre

On Wednesday 6 March, Mr. A. Sandison gave a talk on "Pulse-Code Modulation Developments." The talk was illustrated by slides showing, with block schematic diagrams, how the speech was sampled and views of the equipment. This was an excellent talk as was shown by the questions which followed later.

On Monday 1 April, a party of 30 members travelled to Hewlett Packard at South Queensferry. We were shown the various stages in the assembly of digital voltmeters, oscilloscopes and general electronic test gear.

Our annual general meeting and dinner was held in the Iona Hotel on Wednesday 10 April. The meeting was well attended, some 53 members being present. I was able to report a larger increase in the membership from last session and an increase in our average attendance. This highly successful session reflects the determined efforts of the Committee in seeking an increase in membership and atten-

dances at meetings. The following office bearers were elected or re-elected: *Chairman*: Mr. J. A. Coghill; *Secretary*: Mr. G. A. K. Robertson; *Assistant Secretary*: Mr. M. K. Finland; *Treasurer*: Mr. R. Elder; *Librarian*: Mr. T. Woolard; *Auditors*: Messrs. R. Telford and R. Foulner; *Committee*: Messrs. I. Finlayson, I. Barclay, J. Duncan, M. I. Collins, J. Alexander, L. J. McQuatt, J. P. D. Heatlie and J. King.

G. K. R.

Glasgow Centre

The annual general meeting of the Glasgow Associate Section was held on Friday 3 May 1968, and brought to a close a most interesting session of talks and visits. The average attendance over the session was 32 and we are greatly indebted to the speakers who contributed in such large part to the success of the session.

J. S. M.

Inverness Centre

The Centre completed a successful year with the annual general meeting being held on Thursday 11 April.

The following office bearers were elected: *President*: Mr. J. J. Loughlin; *Chairman*: Mr. J. Fraser; *Vice-Chairman*: Mr. R. I. Thomson; *Secretary*: Mr. W. A. Allen; *Treasurer*: Mr. A. J. Ross; *Librarian*: Mr. B. W. Fieldsend; *Committee*: Messrs. R. H. Inglis, E. J. McLeay, R. Ritchie, L. G. Nuttall, P. M. Bisset and D. Stewart.

Many suggestions were offered for the coming year's program, varying from a talk on "Radio Propagation" to a visit to a pheasant-rearing estate.

After tea a debate took place on the motion "Should we specialize more in the Post Office Engineering Department?" The motion was proposed by Mr. I. Stewart and seconded by Mr. J. Eddie, both of the Associate Section, and was opposed by Mr. A. F. Campbell seconded by Mr. J. W. Innes, both of the Senior Section. A lively debate took place and the motion was carried. The annual general meeting was well attended and the numbers were boosted by a good deputation of members of the Senior Section, who took an active part in the debate.

W. A. A.

Bletchley Centre

The second annual dinner and dance of the Bletchley Centre was held on Friday 16 February at the Regional Training Centre, Drayton Parslow.

Following the success of the previous year it was decided to increase the numbers and this resulted in 120 members and wives attending plus the following distinguished guests: Mr. A. H. C. Knox, Controller, S. E. Region; Mr. E. J. Masters, Regional Engineer; Mr. H. Baker, S.E.E., R.T.C. Bletchley; Mr. A. F. J. Lee, Principal, R.T.C. Bletchley; Mr. J. Missen, E.E., R.T.C. Bletchley; Mr. S. Freeman, E.E., R.T.C. Bletchley.

Also present were two members of the Norwegian Telephone Service who are spending a year in Britain on exchange basis. The special guest speaker was Captain Harry O. Evers, U.S.A.F.

After the toasts Captain Evers spoke on "Difficulties Experienced by American Service Men in Foreign Countries." During his service he has served in Turkey and England. His biggest difficulty in England was getting used to driving on the "wrong" side of the road with his large car. Another great difficulty was our currency system. He had found that houses, restaurants and shops are much smaller and there are very many shops in England which in America would be replaced with one general store where all commodities could be obtained. Another thing that was lacking here was all-night restaurants.

This was a most interesting and enlightening speech both for members and wives. Altogether it was a very successful evening and a well worth-while project.

W. J. A.

Book Reviews

"The Art of Simulation." K. D. Tocher, B.Sc., Ph.D., D.Sc. The English Universities Press, Ltd. vi + 182 pp. 68 ill. 25s.

The technique of simulation is widely used both for engineering and management studies of complex problems which do not lend themselves to direct analytical solution. When this book first appeared in 1963 it was unique in that, until its publication, there had been no book devoted solely to the art of simulation. Since that date a number of books have followed from the United States but none has quite the approach of Dr. Tocher's book. The author is a distinguished statistician who has made significant contributions to simulation studies, and his statistical environment is reflected in the contents of his book.

Topics covered include techniques for sampling from given distributions, the generation of random numbers (the allocation of rather more than 1/10 of a short book to a largely historical account seems undesirable), and the generation of pseudo-random numbers—the chapter on this subject would have been enhanced by some positive guidance as to preferred methods. Other chapters deal with the preparation of flow charts and the problems of estimation of the statistics of observed parameters, and the book concludes with a fairly detailed consideration of simulation studies of queueing systems, both simple and complex.

The first edition of this book was marred by poor proof reading: the errors were too numerous to list in a short review, and the bibliography mis-spelt several authors' names. However, a second impression issued in 1967 removed many of the errors.

Despite the criticism, the reviewer would recommend the study of this book to anyone interested in understanding the principles of simulation. It is to be hoped that the author will be able to prepare a second edition which will remove some of the dead wood, expand on the subject of pseudo-random numbers, and include a critical review of the desirable features of computer-simulation languages. A. C. C.

"Introduction to Elementary Queueing Theory and Telephone Traffic." Petr Beckmann. The Golem Press, U.S.A. 144 pp. 22 ill. \$4.50 hardback, \$3.25 paperback.

This book is intended for people who have a reasonable knowledge of calculus and of elementary probability theory and who desire to gain some understanding of the basis and techniques of traffic theory, particularly as applied to telephone traffic. It stems from the class notes of a summer school conducted by the author for the Bell Telephone Company, and the fact that these notes have been exposed to four such courses means that most errata have been seen and removed.

Opening with a review of elementary probability theory, the book continues with chapters on the Poisson and negative-exponential distributions. The author then considers the behaviour of a single-server queueing system, and multiple channels in a lost-call-cleared system and in a delay system. The next chapter deals with the effect of finite sources and introduces the machine-repair problem. Then follows a most important chapter in which is considered the efficiency of a group of circuits, a topic which has been ignored in some more advanced works. The next two chapters examine the delay times in a queueing system and the effect of queue disciplines. The last chapter makes some suggestions for further reading but makes no mention of the works of Le Gall and Syski. The book concludes with tables for the Erlang loss and delay formulae and includes computer programs in Fortran and Basic for their computation. The reviewer has run the Basic programs with satisfactory results.

The book can be strongly recommended as accomplishing the authors' stated aims. It fills a gap in the published literature, and should satisfy the needs of those people who would like some understanding of the methods and reasoning of traffic engineers, and of others interested in operational research where similar types of problems arise.

A. C. C.

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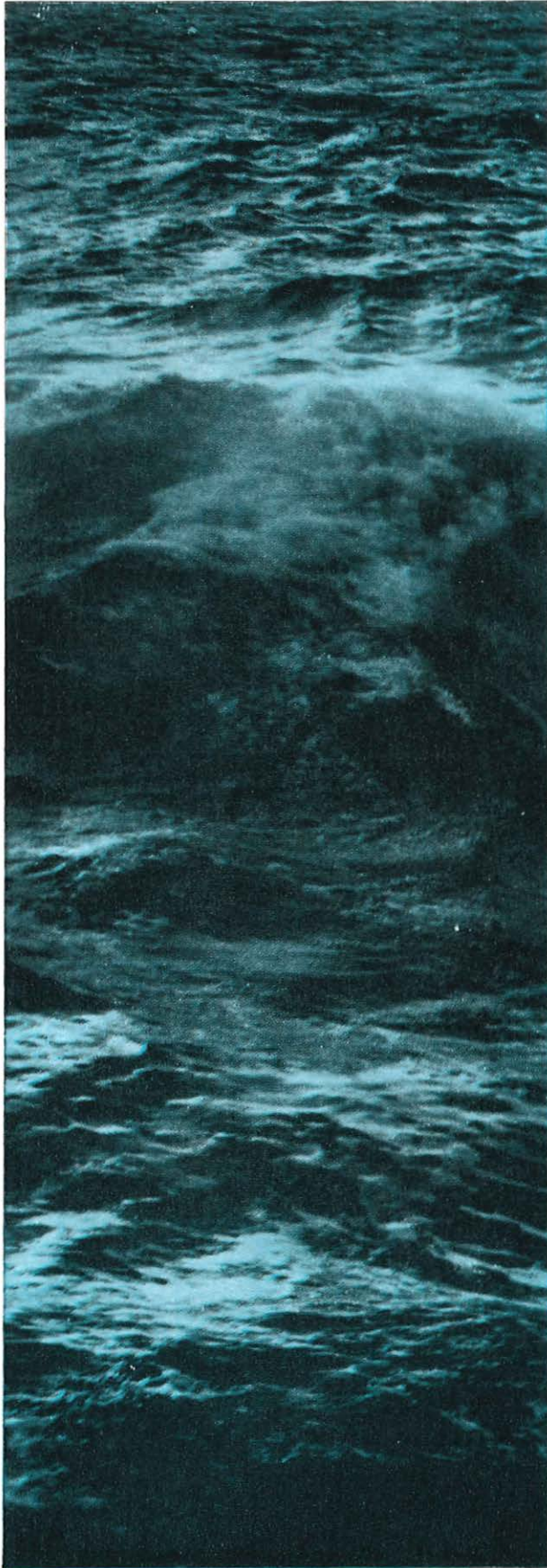
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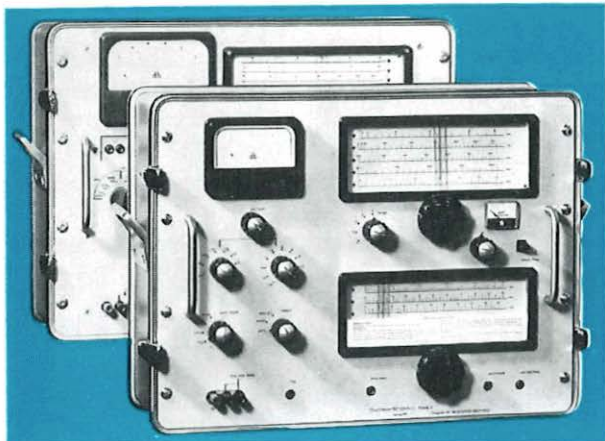
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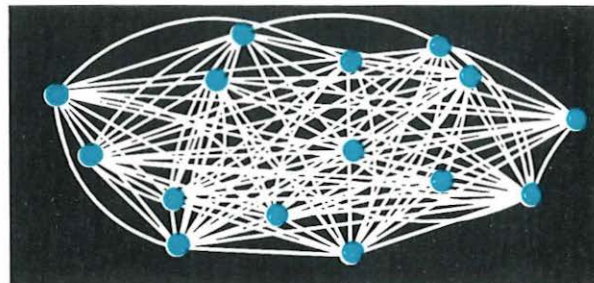


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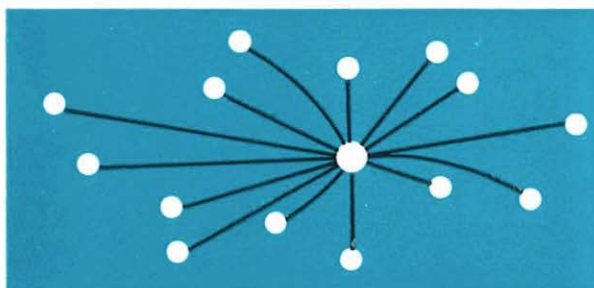
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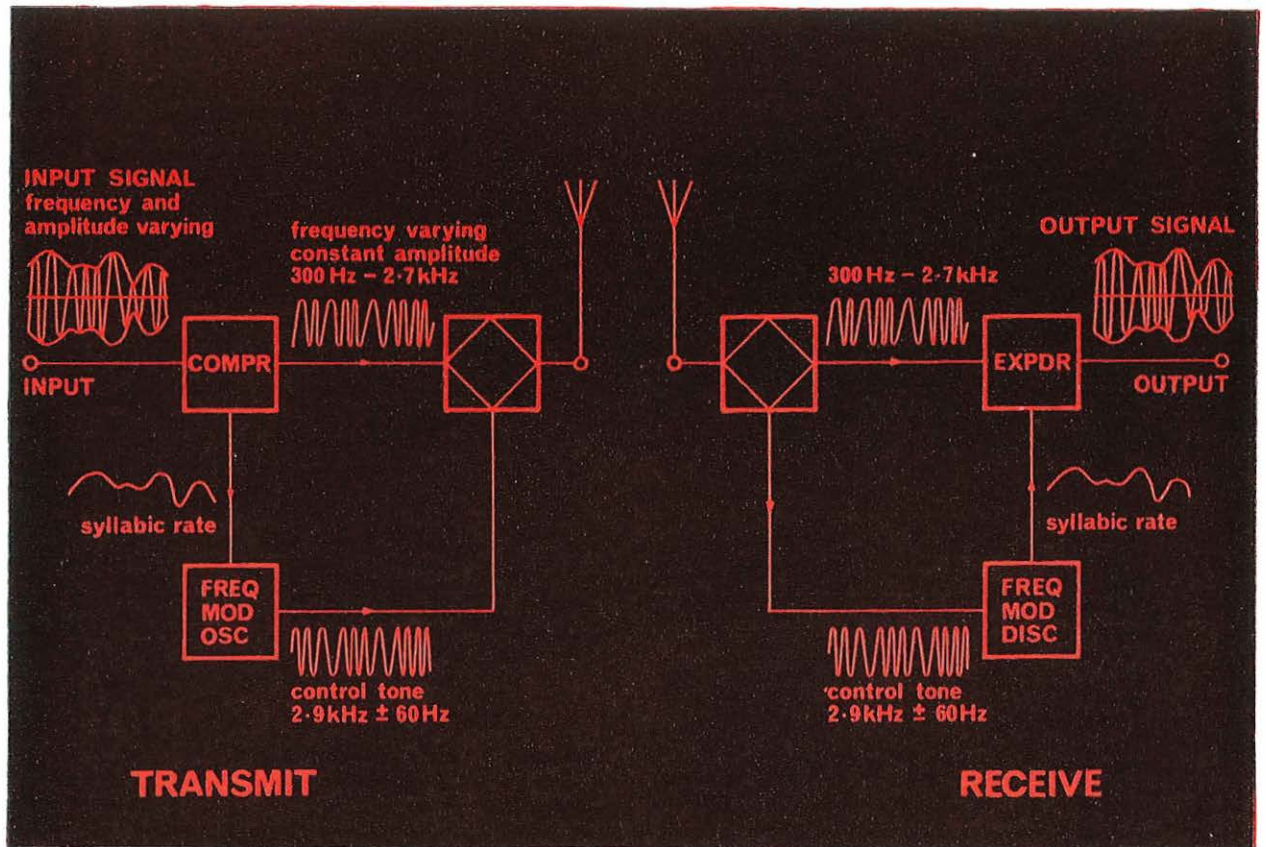
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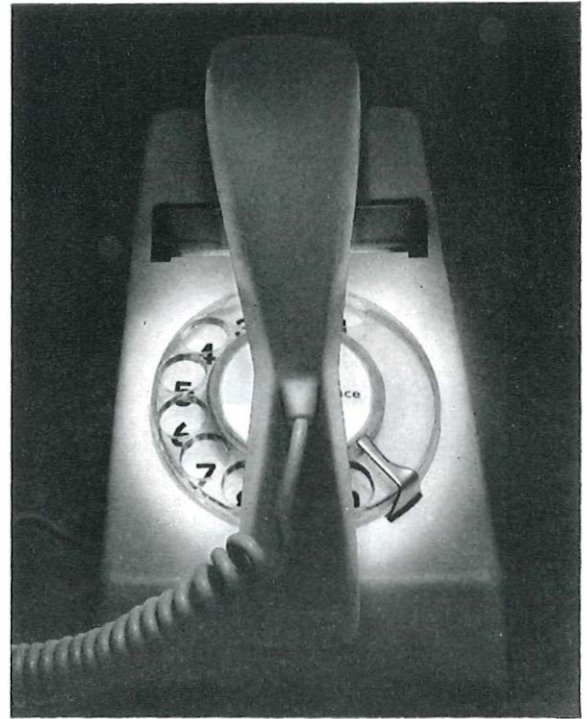
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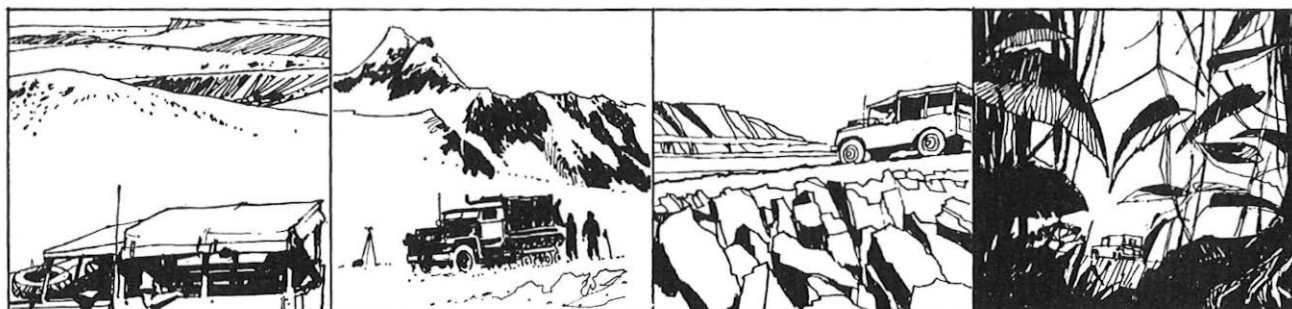
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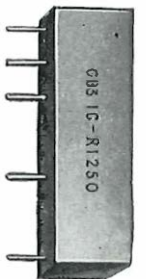
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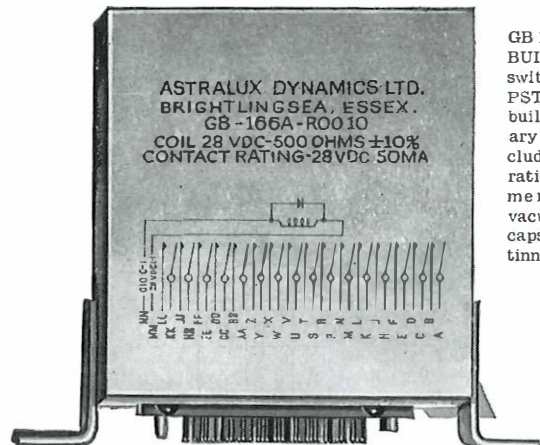
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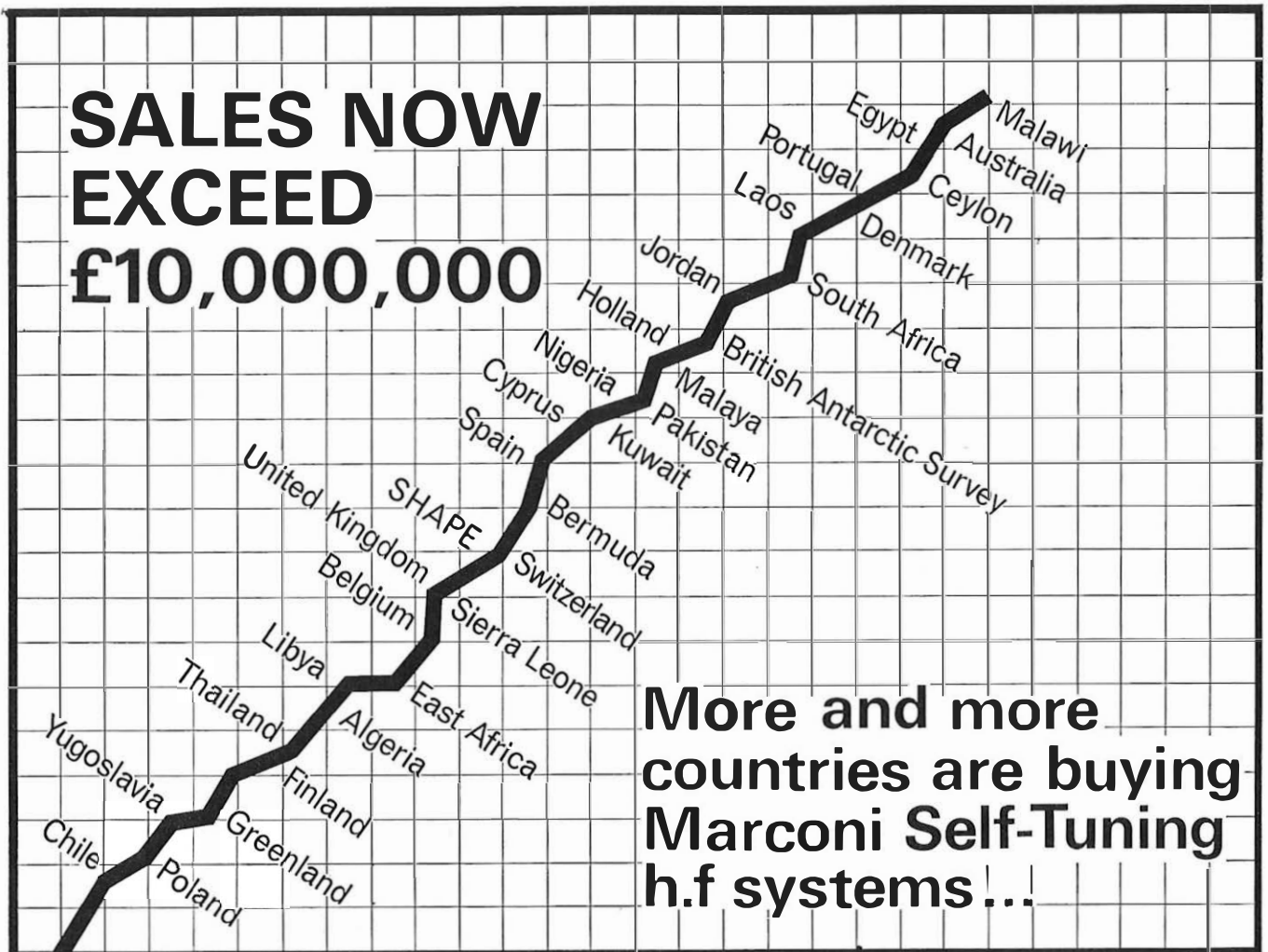
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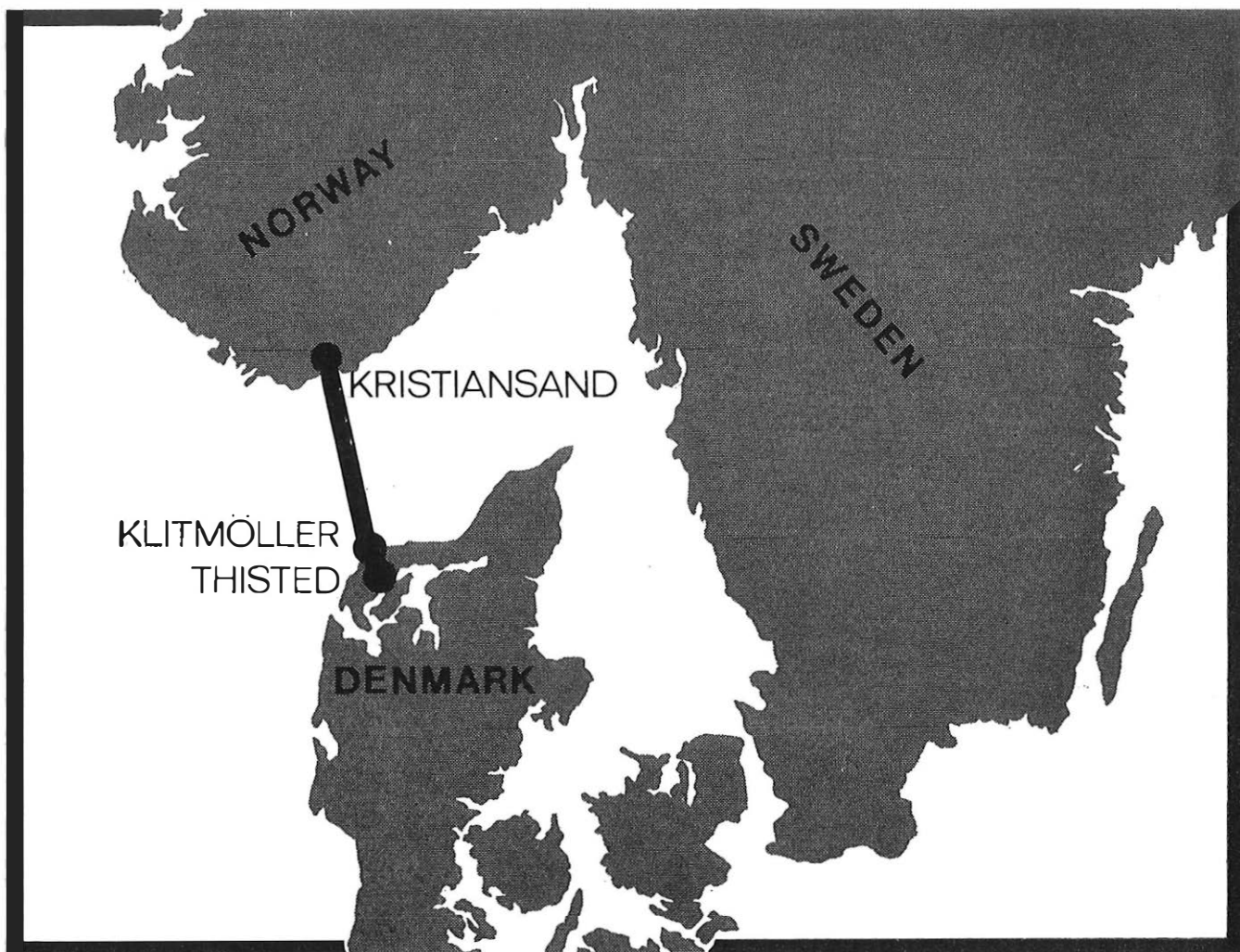
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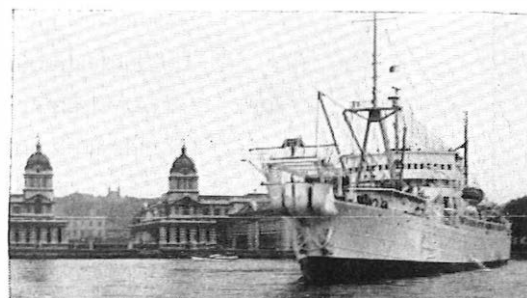
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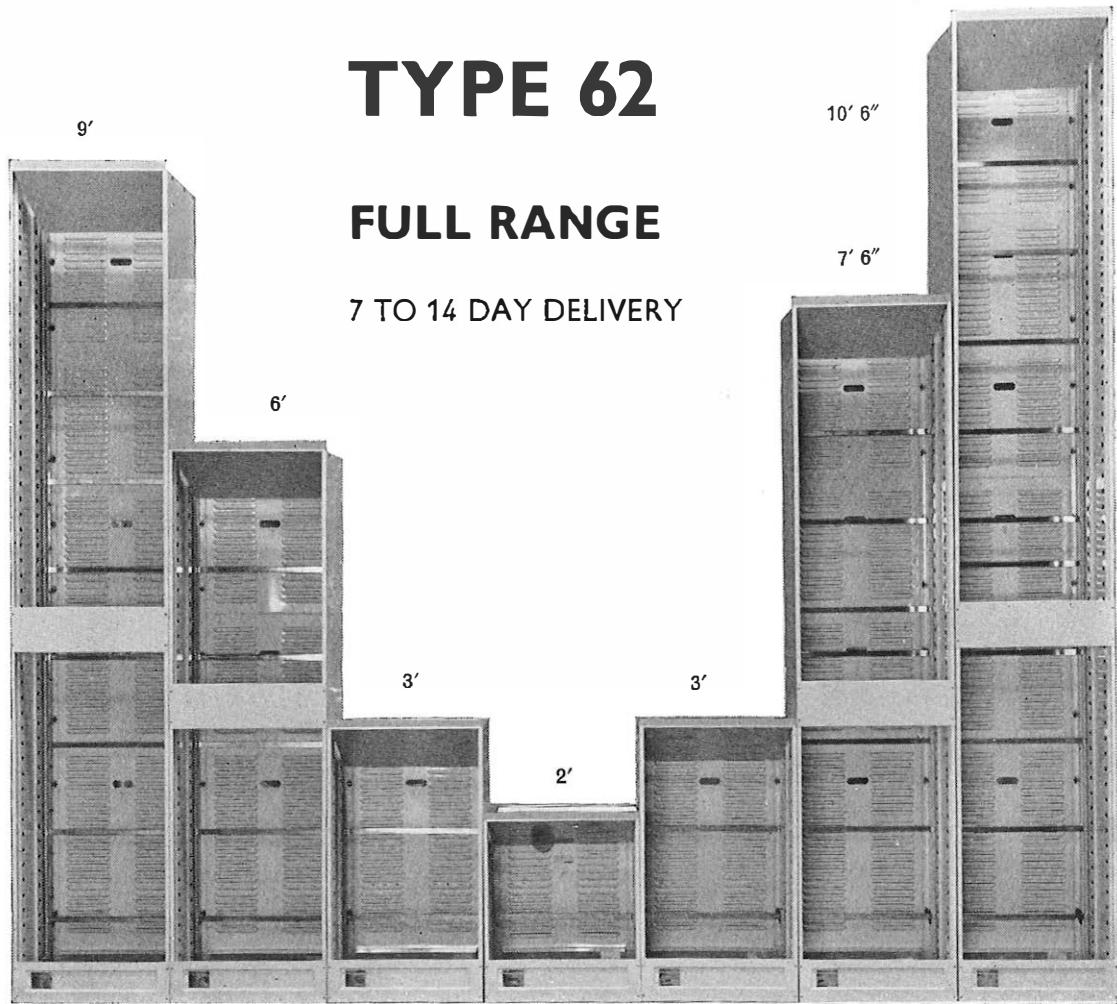
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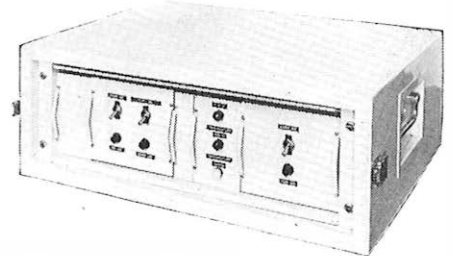
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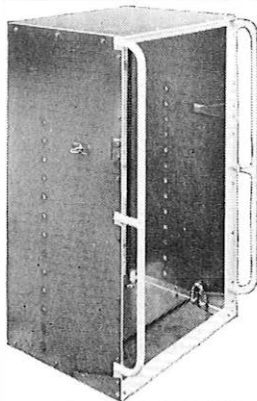
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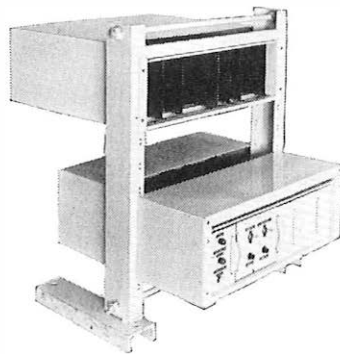
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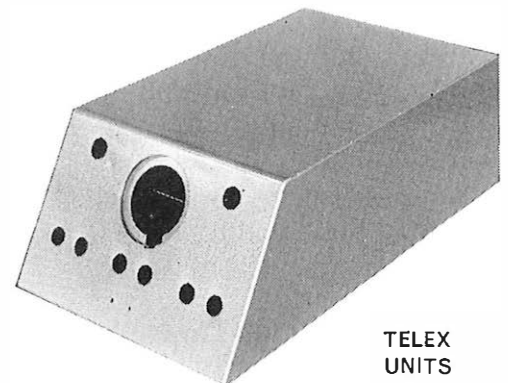
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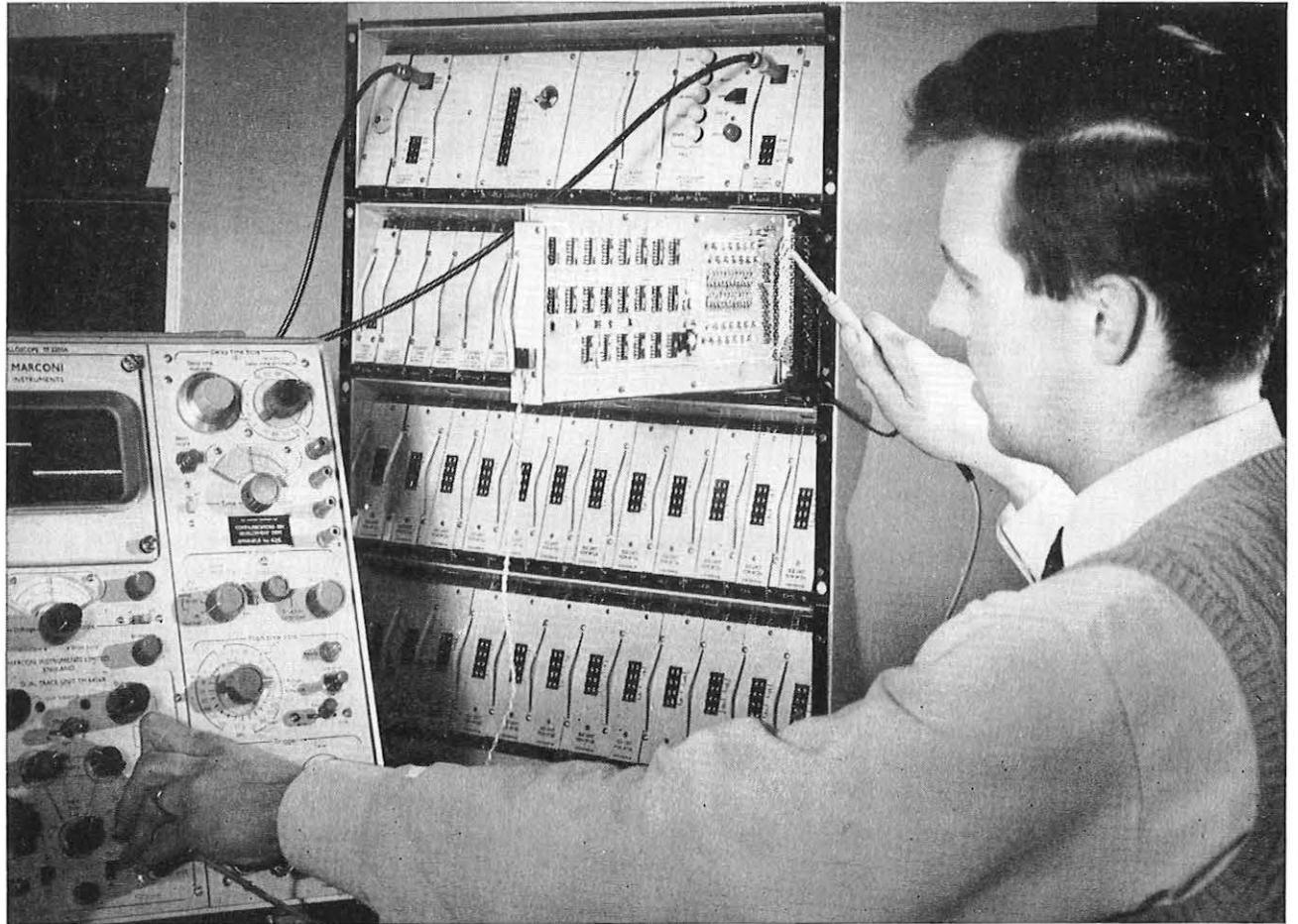


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Telephone : Writtle 451



PRECISION OSCILLATOR TYPE HCD 35



The HCD 35 is a Precision Oscillator specially designed for use as a reference source. Of small size and robust construction, the unit is ideally suited for continuous service under the most stringent conditions.

Oven temperature is determined by proportional control. Provision for fine frequency control by varactor diode.

The unit is very suitable for the exacting needs of transmitter drives and as a reference source for sub-carrier in colour T.V. systems.

Models are available in production quantities on the following frequencies: 4·43361875 MHz 625 line PAL, 4·4296875 MHz 625 line NTSC, 3·579545 MHz 525 line NTSC.

FREQUENCY: Any stated frequency 2–20 MHz.

FREQUENCY STABILITY AND TOLERANCES:

Ageing Rate: Less than 2 parts in 10^8 per 24 hours after 30 days of continuous use.

Change in Frequency with Temperature: Less than ± 1 part in 10^9 per °C. -20°C . to $+60^\circ\text{C}$.

Change in Frequency with Supply Voltage: Less than 1 part in 10^9 for $\pm 5\%$ change in input voltage.

Frequency Adjustment:
Coarse Control $> 5 \times 10^{-6}$.
Fine Control By external potentiometer or D.C. Voltage $\pm 0.5 \times 10^{-6}$ approx.

Conditions of Use: General use between -20°C . and $+60^\circ\text{C}$. The unit may be out of frequency tolerance above this temperature, but will operate up to 85°C .

RF OUTPUT: 0·3 v. peak to peak into 75 ohm load.

WARM UP TIME: The nominal or previous frequency setting will be attained $\pm (5 \times 10^{-8})$ within 45 minutes

POWER SUPPLY: 12·6 volts D.C. 600 mA maximum demand oven cold.

DIMENSIONS: $3\frac{1}{2}'' \times 2'' \times 2''$ (excluding projections).

WEIGHT: 10 ozs. (284 gms.).

OPTIONS: Available for 20–24–28 volts input.

The unit consists of rectangular steel tube cadmium plated, passivated and stove enamelled; finish to DEF 5000. The electrical connections are brought out to a B7G plug in the base of the unit.

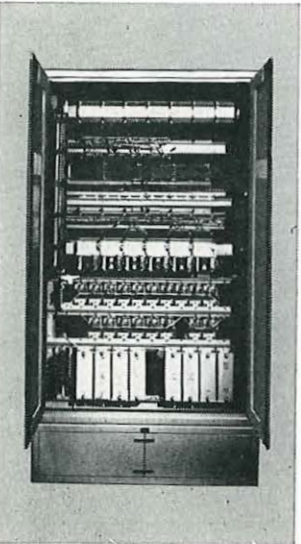
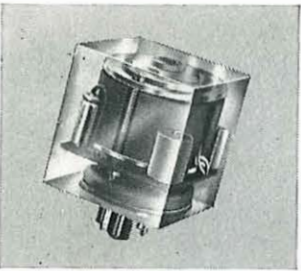
MANUFACTURED UNDER U.K. PATENT 964031

We can also supply appropriate amplifiers, dividers, power supplies, etc., for this oscillator. Your enquiries are welcomed.

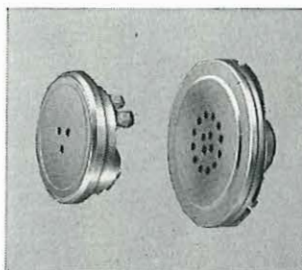
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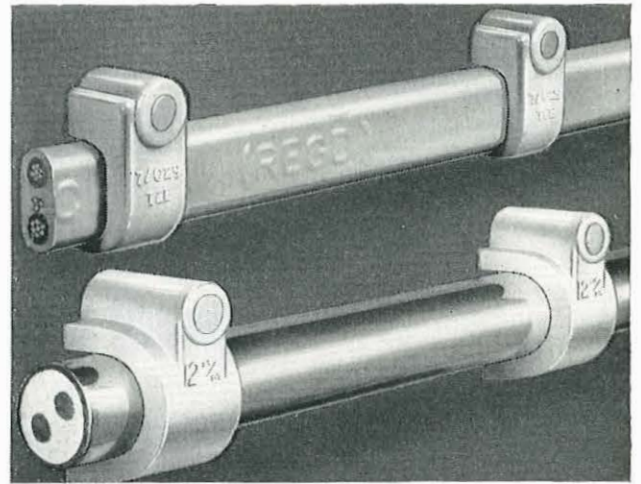
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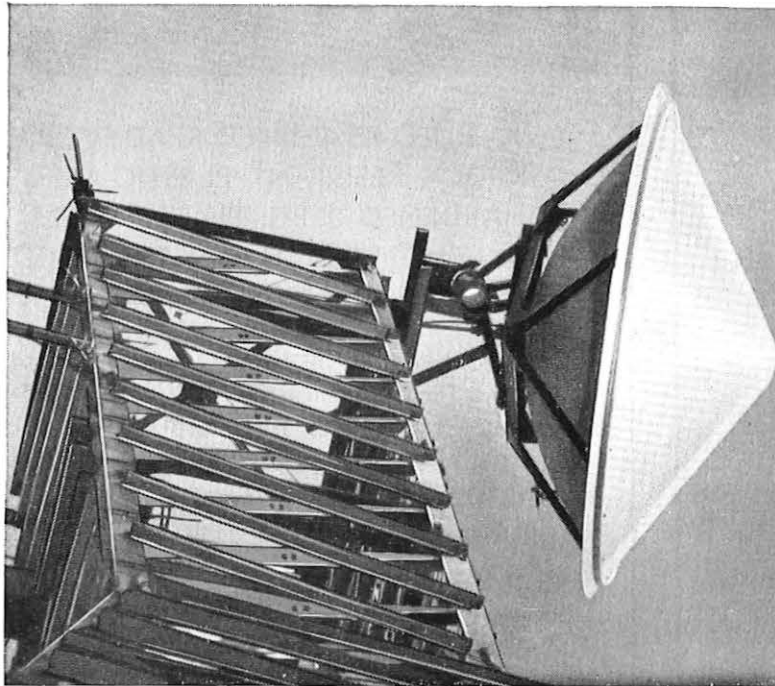
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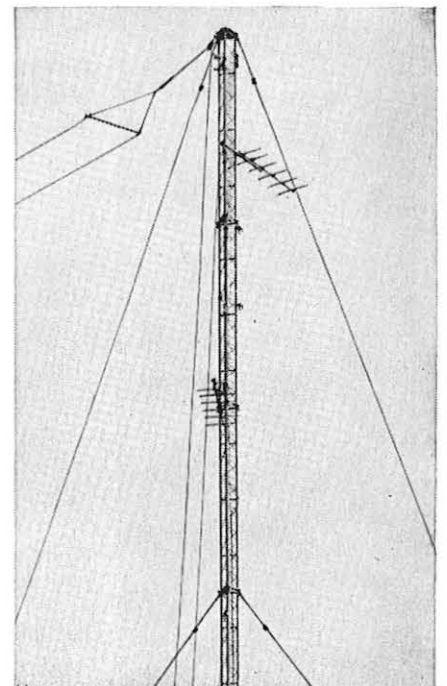
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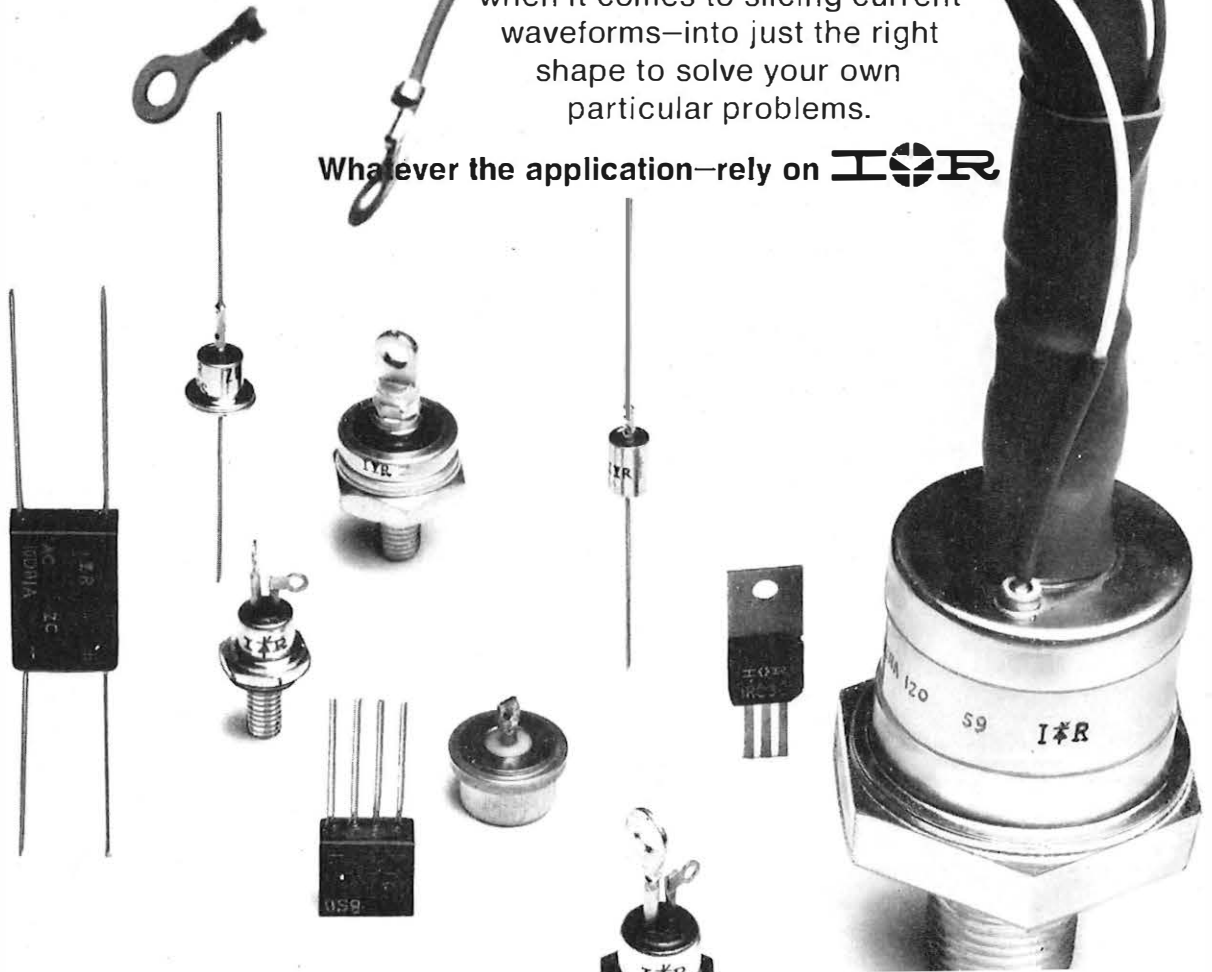
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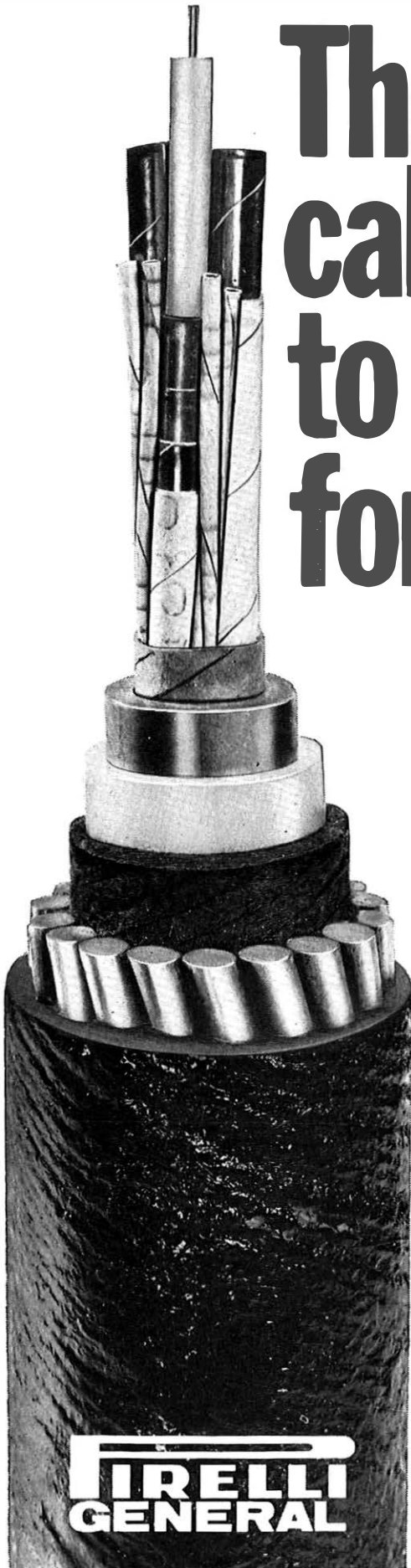
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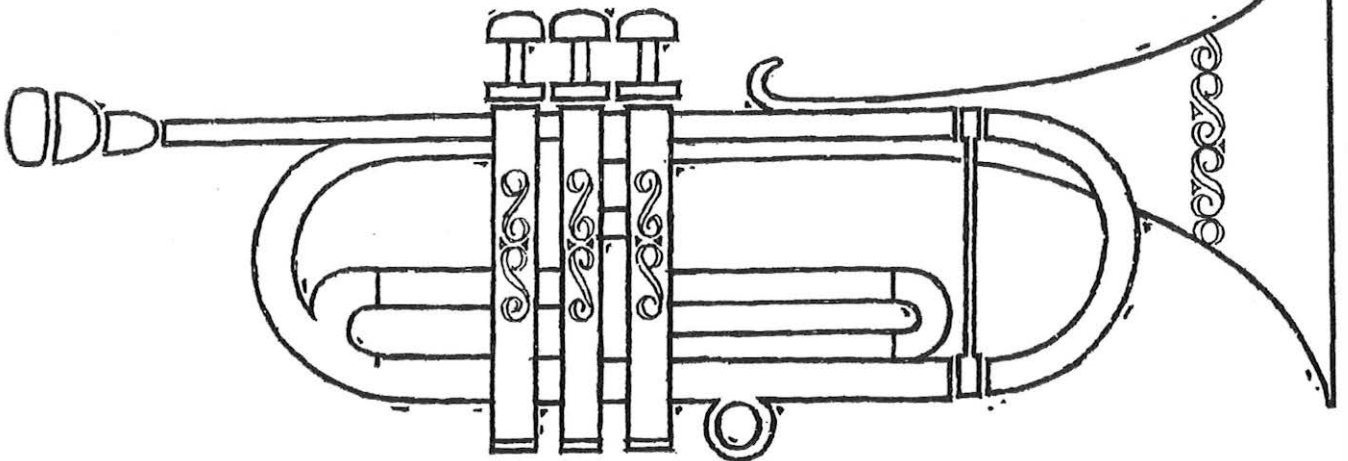
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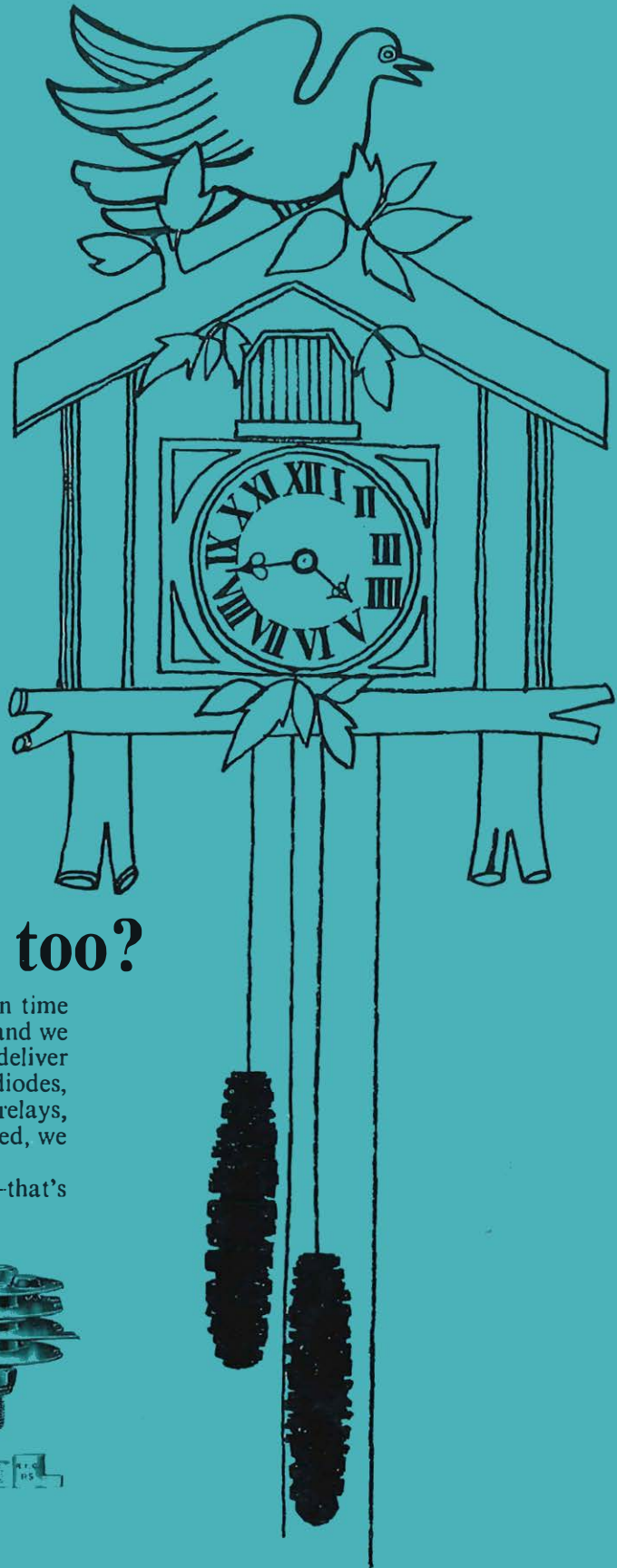
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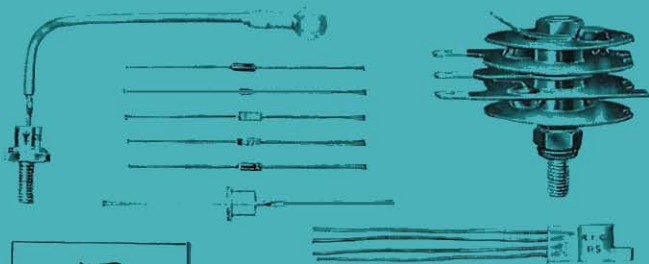




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