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THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

Vol. 60 Part 3 OCTOBER 1967

The Signalling and Switching Aspects of the Trunk Transit Network

W. J. E. TOBIN, B.Sc.(Eng.), A.C.G.I., D.I.C., F.I.E.E.†

U.D.C. 621.395.34: 621.395.38: 621.395.74

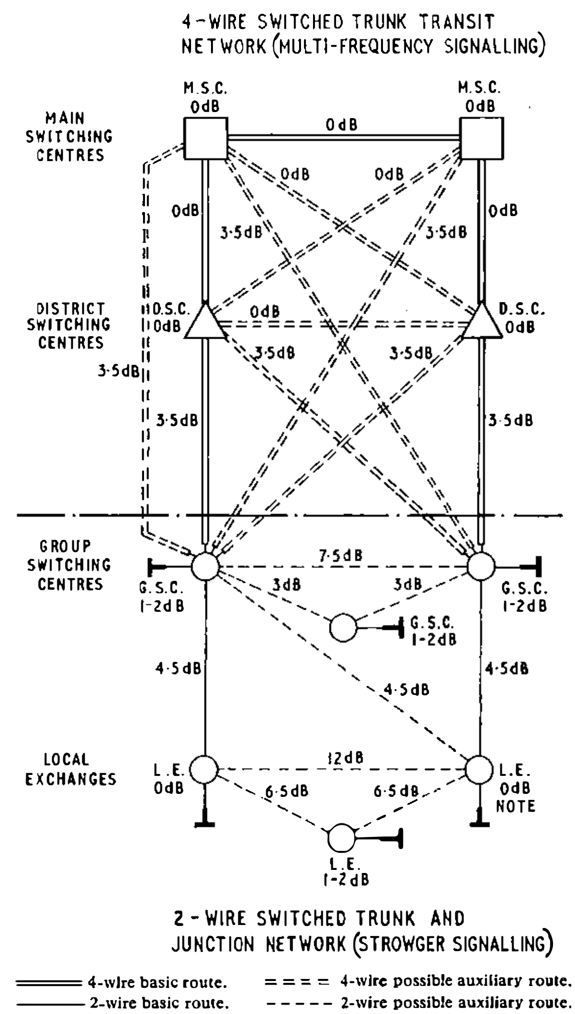
A number of changes have been made in the signalling and switching methods that are to be used for the trunk transit network. The techniques that will be applied are outlined, and the factors that led to the changes are described. The impact of the latest transmission and signalling techniques on future development is also touched on briefly.

INTRODUCTION

IN a previous article in this Journal,[1] the outline plan proposed for the trunk transit network was described. Since that time a number of changes to the signalling and switching proposals have been made, although the transmission features remain unaltered. The principles of the signalling and switching techniques to be applied are outlined in this article, which will be followed by more detailed articles dealing with the technical features of new equipment and changes to existing equipment to enable full trunk-transit facilities to be provided. The first transit switching centres are expected to be opened in 1968–69.

The basic principles outlined previously remain unchanged. Local exchanges will be connected directly to group switching centres (G.S.C.s). The majority of trunk traffic will continue to be carried over direct circuits between G.S.C.s and, for some time, will make full use of existing switching and signalling equipment. New equipment and a separate network of trunk circuits will be provided for the remaining calls, to cater for the requirements of reliable fast signalling and switching and to ensure satisfactory transmission. The general principle of a controlling register-translator at the originating G.S.C., with an "own-exchange only" register-translator at a transit switching centre (T.S.C.), and end-to-end signalling between registers is also retained. Switching at the G.S.C. will be 2-wire and at transit exchanges will be 4-wire, and facilities for automatic alternative routing will be provided at each type of switching centre. At present 37 T.S.C.s are planned, nine of which will be fully interconnected. The fully interconnected T.S.C.s will be known as main switching centres (M.S.C.s), and the remainder as district switching centres (D.S.C.s). The number of trunk transit links switched in tandem will normally be limited to five.

The overall switching plan follows the normal hierarchical pattern applied in many parts of the world and is outlined in Fig. 1, which, for the sake of completeness, also indicates the allocation of transmission losses.



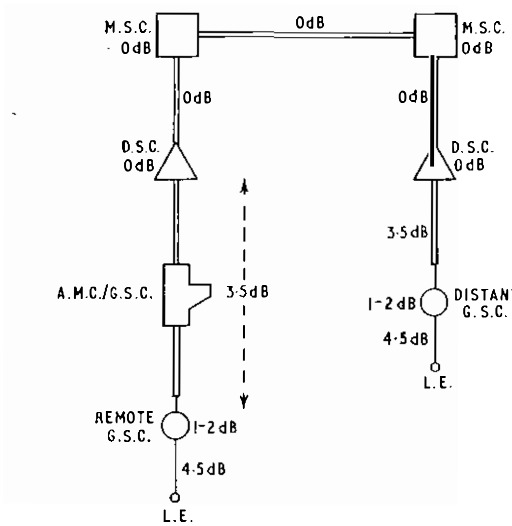
Note: Switching loss at terminal local exchange is included in allowance for subscriber's line and instrument.

FIG. 1—TRUNK TRANSIT NETWORK PLAN

†Telephone Exchange Systems Development Branch, Engineering Department.

A

Even when full subscriber-dialling facilities are available there will still be a residual demand for operator service in trunk switching, and, although general-purpose auto-manual switchboards to handle all classes of traffic calling for operator assistance may be used, it is probable that an auto-manual centre will not be justified economically at every G.S.C. Some auto-manual centres will serve remote G.S.C.s, and, in order to conform to the prescribed transmission limits, these centres will be capable of 4-wire switching when required. The basic routing is indicated in Fig. 2.



——— 4-wire circuits. — — — 2-wire circuits.
M.S.C.—Main switching centre. D.S.C.—District switching centre.
A.M.C.—Auto-manual centre. G.S.C.—Group switching centre.
L.E.—Local exchange.

FIG. 2—STANDARD TRANSMISSION LOSS WITH 4-WIRE SWITCHING AT AUTO-MANUAL CENTRE

SIGNALLING

Inter-Register Signalling

In the earlier article it was stated that a 2-out-of-5 multi-frequency signalling system would be used in the forward direction for the transmission of digital information, and two frequencies different from those used in the forward direction would be used for signals in the backward direction. The signalling equipment was to be associated directly with the registers.

The number of signals available with this scheme was sufficient for the electromechanical system in use. The equipment was designed in such a manner that it would be easy to increase the number of frequencies to six in the forward direction to permit additional signals to be included as new facilities were demanded.

Nevertheless, it became apparent, with the progress that had been made with electronic exchanges and the plans which had been formulated for signalling between such exchanges, that it was desirable to change the approach and provide an inter-register signalling system capable of using 2-out-of-6 frequencies in each direction. Initially, the equipment has been designed for six frequencies in the forward direction and five in the backward direction, but accommodation is left for the addition of equipment to deal with a sixth frequency in the backward direction to provide additional facilities should these be required at a later date.

Since signalling takes place over the 2-wire path in the originating G.S.C., separate bands of frequencies are allocated for each direction of transmission: 1,380–1,980 Hz at 120 Hz spacing in the forward direction, and 660–1,140 Hz at 120 Hz spacing in the backward direction, with accommodation for equipment for an additional frequency of 540 Hz should it be required. The general philosophy of sending a combination of two of the frequencies within the range allocated for a particular direction of signalling to represent a particular function, has been adopted. However, in order to give a high degree of reliability to the signalling function which, at various times, is taking place during the period that the connexion is being set up, and during which there is a liability for surges of interference to arise due to various causes, one combination of two frequencies for each direction is allocated as a prefix signal. All operative signals in both directions are pulse-type signals, each preceded by a prefix signal applied either continuously or as a pulse. The change from prefix to an operative signal is effected without any gap in transmission. Between the originating G.S.C. and a T.S.C., prefix signals are exchanged on a semi-compelled basis. A similar signalling sequence is employed for the transmission of signals up to the first digital signal, in both directions between an originating and a terminal G.S.C.; subsequently, 2-element pulse signals are employed, comprising the prefix signal followed by the operative signal.

Initially the equipment will be capable of transmitting the following signals:

Forward Signals: prefix, decimal digits, and three classes of service (general, coin-box subscriber, and operator).

Backward Signals: prefix, transit proceed-to-send, terminal proceed-to-send, congestion, number received, and spare code.

Later, as electronic-type register equipment is introduced, new equipment will be able to send additional signals in both directions, e.g. send class-of-service.

Line Signalling

Line signalling to provide the seizure, release and supervisory functions will be on a link-by-link basis. The majority of the circuits will employ 1 v.f. in-band signalling using a signalling frequency of 2,280 Hz, the system being very similar in principle to the signalling system S.S.A.C. No. 9.[2] Exceptionally, an out-of-speech-band within-channel signalling system similar to S.S.A.C. No. 8[3] may be used on some of the carrier circuits, and a 4-wire d.c. signalling system may be employed on audio circuits. These three new signalling systems have been designated as follows.

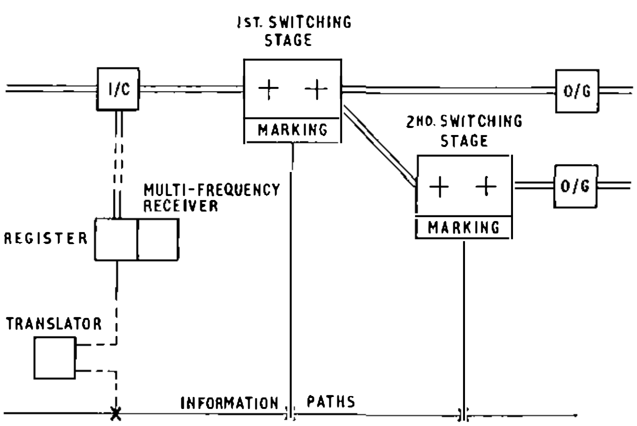
(*i*) In-band system: S.S.A.C. No. 11.
(*ii*) Out-band system: S.S.A.C. No. 12.
(*iii*) Audio system: S.S.D.C. No. 3.

TRANSIT SWITCHING CENTRES

The earlier article referred to the switching at transit centres being based on single-link switching equipment employing two motor uniselectors connected wiper to wiper. The design of this system was satisfactorily completed, and tests of the system over five links in tandem with the various signalling systems referred to above gave excellent results—only one call in a thousand was lost with the repeat-attempt facility rendered inoperative.

However, two factors have arisen which have led to the adoption of a different switching system. Firstly, the single-link scheme assumed that the size of transit exchanges would remain fairly constant, as with growth of traffic more direct circuits would be provided, and that no transit exchange would need to have a capacity of more than 1,000 incoming and 1,000 outgoing circuits. Explosive growth in trunk traffic, coupled with a change of policy relative to the possible extent of usage of the transit network, upset these two assumptions. Nevertheless, it would have been possible to re-design the motor-uniselector link approach to introduce multi-link switching, and in principle a suitable arrangement had been planned. However, this would have called for additional development that would have led to delay in introducing the transit network—a postponement which could not be tolerated.

Secondly, the sudden growth of the telephone system as a whole had led to excessive demands on the suppliers of exchange equipment at a time when, due to the policy of changing to electronic switching as rapidly as possible, it was advisable to limit the extent to which suppliers were asked to involve themselves in appreciable expense in increasing the output of existing standard systems.[4] Accordingly a decision was taken similar to that taken in the local-exchange field—that is, an existing crossbar system available in this country was chosen to be used in transit exchanges. For these exchanges, however, the Standard Telephones and Cables, Ltd., BXB 1121 system was chosen. This system has been developed by the manufacturer from a basic crossbar system to provide the facilities required by the Post Office. Details of the system will be given in a later article, but the basic trunking arrangement is shown in Fig. 3. Initially, at least, the external circuit terminations will be sensibly the same as those developed for the motor-uniselector system, modified only as essential to work into the crossbar equipment.



I/C—Incoming O/G—Outgoing

FIG. 3—BLOCK SCHEMATIC DIAGRAM OF BXB 1121 TRANSIT SWITCHING CENTRE

Fig. 3 shows how connexion between an incoming and an outgoing circuit can be effected, in some cases via a single stage of switching and in others via two switching stages. In both instances the crossbar switches are marked in accordance with information passed from the translator to the appropriate switching stage. The marking information is derived from the group code received and stored in the register.

THE FUTURE

Transmission

Experiments are already being carried out to determine the practicability of improving the balance return-loss at the 4-wire to 2-wire conversion point of existing G.S.C.s to enable the transit network to be operated at a nominal transmission loss of 3 dB (rather than 7 dB), with a consequent improvement on calls routed over it. The nominal maximum loss between local exchanges over this routing is planned to be 16 dB. Further, with the introduction of electronic G.S.C.s, it is envisaged that the trunk-switching train will be switched on a 4-wire basis, i.e. the 4-wire/2-wire termination will be on the local side of the G.S.C., with individual balances per junction and amplification in the 4-wire circuit within the exchange, thus permitting an overall loss, from local exchange to local exchange, of 6 dB when both incoming and outgoing G.S.C.s are so equipped. Finally, of course, there is the probability of using pulse-code-modulation (p.c.m.) transmission techniques over various forms of transmission media, which may have a revolutionary effect on transmission performance.

Signalling and Switching

There is a number of drawbacks to signalling over speech paths, although it must be admitted that some compensating advantages are apparent. However, on balance it would appear that, for the future, greater flexibility of operation of the system, leading to overall economies and improvement in service, could result from the adoption of an entirely separate channel for signalling all forms of information relative to setting-up and clearing-down calls. The transfer of information would be by means of high-speed serial data operating at, say, 2,400 bauds, thus enabling one signalling channel (with a standby channel) to serve several hundreds of circuits. In concept this approach is simple, and already, in the International Telegraph and Telephone Consultative Committee (C.C.I.T.T.), such a system is being studied for international use. The major problem arises in grafting such a system into an existing network, particularly so far as switching controls are concerned, and there is no doubt that a switching system with a form of control devised to work with such a method of signalling would be the ideal for the full benefit from separate-channel signalling to be achieved. Nevertheless, preliminary thought is being given to the possibilities of developing such a signalling system in such a way that it may be used with existing exchanges without detriment to its use with exchange controls designed to exploit its full capabilities.

Against this, as stated above, p.c.m. transmission will undoubtedly become a feature of transmission media, and already a trial of integrated p.c.m. transmission and switching for local junction networks is planned.[5, 6]

Should this prove successful and extend to the trunk network, it may well have an effect on the foregoing, although it is perhaps too early to express an opinion on this aspect.

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Post Office Relay Type 2D

U.D.C. 621.318.562

A two change-over contact-unit version of the Carpenter-type polarized relay has been developed for telegraph and telephone use. Although more complex, and requiring more precise adjustment than the single change-over contact-unit relay, the new relay has proved very satisfactory in service.

THE British Post Office Relay Type 2D is a two change-over contact-unit version of the earlier, single change-over contact-unit polarized (Carpenter) relay, known in the Post Office as the Type 2B.*

The Type 2D relay has been in Post Office use in its present basic form since 1959, initially as a telegraph pulse-repetition relay and, more recently, for a similar function in telephone equipment as well as in pulse-correcting elements.

The earliest use of the Type 2D relay was about 1950–51 in "island radio-link" equipment, and at that time they were made in limited numbers in the Telephone Manufacturing Company's model shop. As can be seen from Fig. 1 (*a*) and (*b*), they were produced by modifying the contact arrangement of the Type 2B relay, retaining its contact-adjusting screws. Each screw-adjusted contact assembly contained two separate contact members, and, in order to ensure correct mating with their respective armature-mounted contacts, the plate on which they were assembled was arranged so as to allow a small swivelling motion, damped by an adjustable friction device.

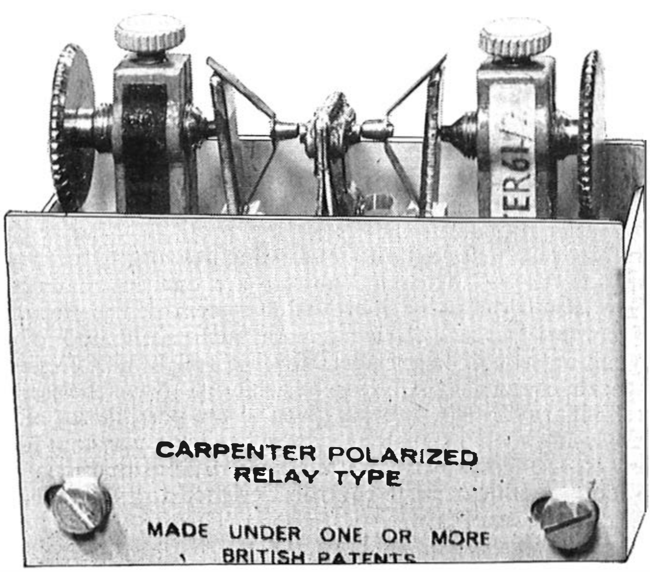
Only a few of these relays were made; when they had been correctly adjusted they worked well, but it required considerable patience and skill to reach this state. Also, at that time there was no immediate prospect of further use, and the quantities involved made the design an uneconomic proposition.

A few years later it became evident that an either-side stable, two change-over contact-unit, polarized relay would be useful in both telegraph and telephone signalling and switching circuits. Accordingly the Telephone Manufacturing Company undertook a complete redesign, which has resulted in the present relay Type 2D, with the contacting arrangement illustrated in Fig. 2.

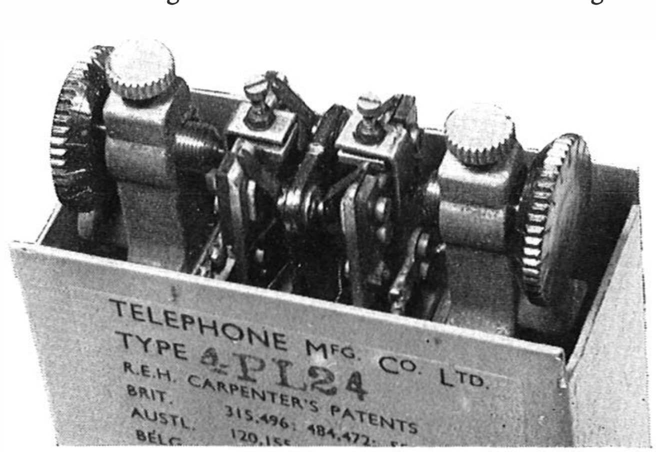
In the new design all the component parts, i.e. armature, contacts, magnets, etc., are mounted on a one-piece Mycalon moulding; this arrangement minimizes variations of relay performance with temperature and age.

The polarizing permanent magnets are associated with the electromagnets as indicated in the schematic diagram

*TURNER, H. A., and SCOTT, B. A Polarized Relay of Improved Performance. *P.O.E.E.J.*, Vol. 43, p. 85, July 1950.



(*a*) Type 2B Relay



(*b*) Modified Contact Arrangement

FIG. 1—MODIFICATION OF TYPE 2B RELAY TO PRODUCE ORIGINAL VERSION OF TYPE 2D

of the magnetic circuit shown in Fig. 3. Each polarizing magnet is provided with a variable soft-iron shunt that is positioned during manufacture to adjust and balance the polarizing flux; the shunts are then locked, as any subsequent movement will make the relay impossible to adjust under normal maintenance conditions.

The four contact points which move with the armature, i.e. two per change-over contact-unit, are mounted on compliant springs to minimize contact bounce, while the armature cross-head can twist slightly to balance the contact forces. In combination, if the initial setting-up of the screw-adjusted contact points is incorrect, these two features can allow the armature to take up a position along one or other diagonal of the configuration formed by the four screw-adjusted contact points. To avoid this condition it has been found necessary during adjustment to use lamps to indicate which of the two contact circuits is established at any time by either change-over contact-unit. Relay energization is gradually reduced and, at each lower energization, the contact openings and the relative

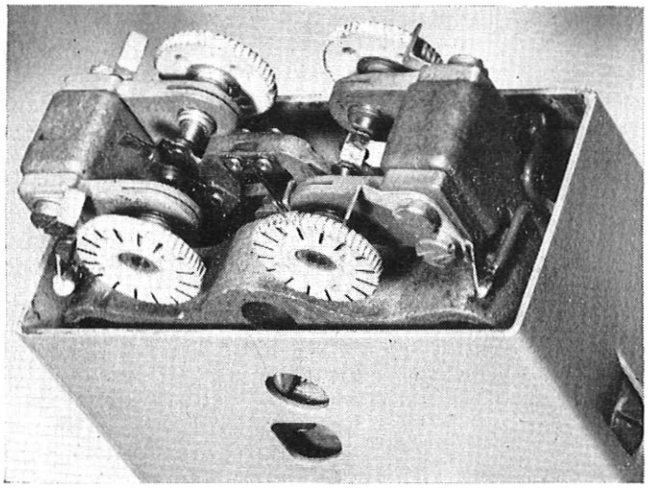


FIG. 2—CONTACT ARRANGEMENT OF PRESENT TYPE 2D RELAY

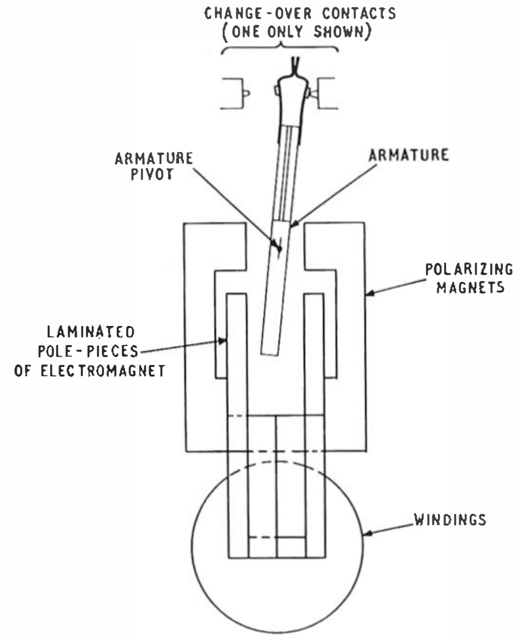


FIG 3—SCHEMATIC DIAGRAM OF MAGNETIC CIRCUIT

contact positions are adjusted until the armature changes over correctly. This process is continued until the relay switches correctly at an energization of 1 ampere-turn, in which condition the contact opening is less than 0·0005 in. Experience shows that, provided this adjustment has been carefully made, the screw-adjusted contact bearers can each be withdrawn a specified distance for the relay to meet its designed requirements.

Although this relay is a more complex device than its predecessor, the Type 2B, and requires a more exact adjustment technique, it has been found in service to have a stable performance, and fully to have justified its introduction.

B.H.E.R.

Book Review

"Electric Lifts." R. S. Phillips, M.I.E.E. Pitman and Sons, Ltd. 485 pp. 339 ill. 84s.

This is the fifth edition of a work which has become the standard textbook on the design, installation and maintenance of electric lifts. The first edition was published in 1939 and the fourth in 1958.

The new edition follows the method established by its predecessors; the principles involved are illustrated by detailed descriptions of the best current practice in the British lift industry. This is supplemented throughout by sound practical advice. Comment has, therefore, been restricted to the changes which are to be found in the new edition. These, with a few exceptions, bring up to date the information given in the previous editions. Descriptions are given of recent developments such as closed-loop control of lift motors, signal-control systems for groups of high-speed lifts, and controllers using static switching. Again, each of these is illustrated by giving an account of a successful current design. The section on solid-state control of lifts is confined to a detailed account of a logic system designed around Norbits, and does not fully explore the principles and possibilities of what is likely to become standard technique in the next decade. Useful additional information has also been included on a variety of matters such as multi-storey flat lifts, fire precautions, and costs.

One general criticism is that the 18 per cent increase in the number of pages in the book and the 33 per cent increase in price has not been accompanied by a corresponding increase in useful information. Descriptions of obsolete equipment and unhelpful illustrations have been retained, and the space they take could have been used to better advantage. Nevertheless, the book will remain an indispensable reference for engineers, students, architects, and all others engaged in or interested in lift work.

P.E.M.

Conveyance of Mail by Electric Vehicles

D. H. SANDER†

U.D.C. 656.86:629.113-83

As part of the present program of postal mechanization, a range of electric vehicles has been introduced to reduce the cost of operation, and to speed the handling of mail between railway stations and sorting offices and the delivery of parcels in towns throughout the country.

INTRODUCTION

PROPRIETARY electric vehicles of the driver-ridden platform and tractor type have been used for railway-station and postal use since 1902. A description of the trucks used up to 1944 is given in an earlier article in this Journal.*

By the end of the last war the total number of vehicles had risen to 80, and experiments were carried out with other types of proprietary electric vehicle with minor alterations to suit Post Office requirements. The Brush Pony driver-ridden, and the Harbilt and Electruk pedestrian-controlled, types of platform truck were supplied for use on the public highway between railway stations and sorting offices. These vehicles, which were capable of carrying a load of 1 ton and of towing one trailer similarly loaded, proved successful and are still in use today.

With the increase in road traffic and its attendant parking problems it became more difficult to maintain a proper parcel-delivery service in town centres using motor vans, which tend to become costly in use due to the number of short movements in low gear. Trials were carried out with pedestrian-controlled trucks having aluminium-faced Plymax bodies, with sliding doors on both sides, which facilitated the "preparation" of parcels before delivery. This type of vehicle has proved so successful that there are now some 340 in use throughout the country, with no apparent slackening of demand in the foreseeable future.

Although by 1964 the electric-vehicle fleet on railway-station services had risen to 200, consisting mainly of Greenbat platform trucks, Brush Pony platform trucks, and B.E.V. and Scott tractors, there was a rapid increase in the demand for mechanical aids, much of which could not be fulfilled by proprietary equipment, and it became apparent that a comprehensive range of vehicles would have to be designed to cater for the many mail-handling problems that had arisen. The specifications produced, whilst they are primarily based on Post Office requirements, are such that most manufacturers of this type of equipment would be able to supply vehicles to comply with them either by modification of their standard product or by the production of a new model within the scope of their experience.

†Postal Engineering Branch, Engineering Department.

*PHILLIPS, R. S. Electric Battery Vehicles for Postal Work. *P.O.E.E.J.*, Vol. 37, p. 48, July 1944.

TRACTORS

Steep gradients of up to 1-in-8 are common on railway stations and, because the public usually has access to them, they present special problems of traction and braking, particularly where trailers are not equipped with over-run brakes, which operate when the tension on the tow bar is removed. Experiments have shown that for the safe negotiation of slopes of this nature a tractor must be heavy and have large pneumatic-tyred wheels to reduce the tendency to slew and cause the trailers to "jack-knife" when stopping in an emergency.

FIG. 1—ELECTRIC TRACTOR

Three-wheel, front-wheel drive tractors are generally unsuitable for working on gradients, and it was, therefore, decided that, as far as possible, the standard requirement should be a four-wheel rear-wheel-drive tractor, with either a heavy-duty or light-duty body to suit local conditions.

The illustration (Fig. 1) shows an example of the current light-duty tractor which, with its short wheelbase, is as manoeuvrable as its 3-wheel predecessors but possesses superior traction and braking power. The wrap-round body is made from $\frac{3}{16}$ in. steel plate ($\frac{3}{8}$ in. on the heavy-duty body), and all accessories, such as lamps, etc., are recessed as a precaution against damage. The horse-power of the motor and the capacity of the battery are determined to suit site conditions such as distance to be covered, slopes to be negotiated, number of trailers, etc.

Because of the poor general lighting which may be encountered, all tractors, in common with all other vehicles used on railway stations, are now painted golden yellow, with black wheels and chassis, to conform with the standard code of practice for safety colours.

The tractor is the commonest form of mechanical aid for station work, and current orders have risen to 50 per year.

STATION TRUCKS

Station trucks are of the driver-seated platform type, designed for use in the station area where relatively small quantities of mail are required to be moved over fairly long platform distances. A short wheelbase gives good manoeuvrability and, with their improved braking efficiency, they will be used as a replacement for existing types of platform truck.

It is not expected that the demand for this type of truck will be great, but the facility of being able to drive in and out of lifts without the need to hitch and unhitch trailers has been found to be of considerable value on certain stations where time is an important factor.

The trucks have sufficient capacity for approximately 14 parcel bags or 15 cwt, and are capable of pulling up a 1-in-12 gradient two similarly loaded trailers.

ROAD TRUCKS

Road trucks are designed for use with relatively light loads between railway stations and sorting offices, where short distances on the public highway have to be traversed and the use of a motor vehicle would be uneconomical.

Three-wheel trucks having single chain-driven front wheels cannot readily use a sprung suspension at the front, and provide a very hard ride. The new types of truck have sprung suspension on all wheels, and the drive is on the rear wheels via a differential gear. Whilst the platform dimensions and towing facilities have been standardized, the manufacturer's own standard moulded fibre-glass weather-proof cab is accepted provided that it is within certain dimensional limitations. Wooden drop-sides with netting over the top are provided to secure the load.

The power of the motor and the capacity of the battery are sufficient to drive the truck for a distance of 12 miles per day, over average road conditions, whilst carrying a 1-ton load and towing a trailer similarly loaded.

Road trucks suffer from the disadvantage that the vehicle has to remain idle whilst waiting to be loaded and unloaded, and, at some stations, tractors have been found to be more suitable despite the legal limitation of towing not more than one trailer on the public highway. The present tendency is for a combination of road trucks and tractors to be used for short road hauls.

PEDESTRIAN-OPERATED VEHICLES

Station Truck

Where the distance between the railway station and sorting office is very short, and if the quantity of mail is fairly small, the most suitable type of vehicle has been found to be a pedestrian-controlled platform truck, fitted with end rails and side chains, which can carry a load of 1 ton and tow a similar load.

Earlier types of pedestrian-controlled station truck had proved so successful that only minor changes in design were necessary to give more protection to lights and other vulnerable equipment, such as switches, and to provide cushion instead of pneumatic tyres.

Increasing use is now being made of the pedestrian-operated station truck (see Fig. 2) as a replacement for the sack truck on station platforms where several journeys would otherwise have to be made, and about 80 are in use at the present time.

FIG. 2—PEDESTRIAN-OPERATED STATION TRUCK

Tug

The pedestrian-operated tug is a new design and will be used on similar duties to the pedestrian-controlled station truck. Its great advantages are good manoeuvrability and small size, which allow it to be used on narrow station-platforms and in station lifts where there are limitations on size. Whilst the tug will pull a number of trailers it is not suitable where steep down-gradients have to be negotiated, due to its light weight and consequent low braking power.

The tiller arm, drive motor, transmission, braking system and driving wheel are combined as a single unit within a turntable mounted on the chassis, which carries the battery and control gear (see Fig. 3). The two wheels at the rear of the chassis are fitted with brakes for parking purposes.

With the introduction of through-container working, using the railway BRUTE trailers (British Rail Universal Trolley Equipment) and the Post Office Universal Trailer for loose parcels, it is expected that there will be an increasing demand for this type of pedestrian-operated tug for moving containers within sorting offices.

FIG. 3—PEDESTRIAN-OPERATED TUG

Trolley

The pedestrian-operated trolley is another new design for use as a replacement for one or more sack trucks. With a capacity of six parcel bags or 10 cwt, its principal use will be on narrow railway-station platforms and where small lifts have to be used, as shown in Fig. 4.

The two centre wheels are driven, and the load is balanced on one of the two end castor-wheels. Expanded-metal guards are fitted at each end of the platform to support the load.

The trolley, which can turn about its centre, is extremely easy to manoeuvre and is expected to be of value within sorting offices as well as for station use.

Delivery Truck

The pedestrian-controlled delivery trucks have a capacity of 100 ft^3, and are used in town centres for the delivery of parcels and telephone directories in loads weighing up to 1 ton.

The body and sliding doors are made from fibre-glass, which presents a more pleasing appearance than the earlier types, which had heavier aluminium-faced plywood bodies. The reduction in weight also allows economies in battery capacity.

FIG. 4—PEDESTRIAN-OPERATED TROLLEY

FIG. 5—PEDESTRIAN-OPERATED DELIVERY TRUCK

In recent years the trucks (see Fig. 5) have been fitted with soft solid-rubber tyres, which have double the life of the equivalent pneumatic ones and require no maintenance or source of compressed air.

METHODS OF CONTROL

Experience has shown that difficulties may arise if a driver has to use trucks of different manufacture having differing methods of control. The design of the tiller on all pedestrian-controlled vehicles and the method of control have been standardized, and the controls of driver-ridden vehicles follow conventional motor-car practice as far as possible.

TOWING ARRANGEMENTS

A considerable variety of towing hooks is in use throughout the Post Office and the railway system, and, to cater for the majority of these variations, all tractors, tugs and station trucks are provided with two types of towing gear, as illustrated in Fig. 6. The V-shaped tow

FIG. 6—TOWING GEAR

bar is used for the railway BRUTE and the Post Office Universal Trailer, and the safety tow-hook or draw bracket with the tow-hook removed are used for other types of trailer.

MAINTENANCE FACILITIES

The lack of space and facilities on railway stations present a number of maintenance problems, and one of the commonest difficulties is the maintenance of tyre pressures, which are normally in the range 70–90 lb/in^2. The provision of solid tyres does not provide a simple solution, due to their loss of traction and braking efficiency on gradients, and trials are being carried out with other types of cushion tyre.

BATTERIES AND CHARGING EQUIPMENT

Alkaline cells were often used in the past where engineering staff were not readily available for battery-charging, but the lower charge-discharge efficiency of such cells, and their poor performance on gradients towards the end of discharge, made them inferior to the lead-acid counterparts.

The introduction of the automatic charger using a charge-timing relay made the correct care of the lead-acid battery much less dependent on the attendance of engineering staff, and, in consequence, lead-acid batteries are now used for all vehicles except those maintained for reserve purposes.

Single-rate chargers that complete the charge in 11 hours were formerly used, but, recently, to meet the increased demands on existing tractors, their daily availability was increased by the fitting of 2-stage 8-hour charging equipment. This equipment, which charges at a high rate until a voltage of 2·5 volts per cell is reached and then at approximately the 15-hour rate for a preset period of up to $3\frac{1}{2}$ hours, is now supplied with all vehicles with the exception of parcel-delivery trucks, which only work an 8-hour day.

CONTROLLERS

Conventional controllers using series resistance in the form of a carbon-pile or contactor-switched resistor are wasteful of power, and in recent years considerable advances have been made by manufacturers in the production of efficient solid-state controllers that will allow a vehicle to have a longer working day for a given size of battery.

Trials are now being carried out with electric tractors using cell-switching and thyristor pulse-type controllers, to observe their reliability and maintenance costs compared to contactor controllers.

With the use of the cell-switching controller, the battery is divided into a number of units which, joined in series and parallel combinations, give the required gradation in voltage steps for smooth acceleration. Contactors and silicon-diodes are used to switch the cells, and, in practice, series resistance is usually inserted during the early stages of acceleration.

The thyristor pulse-type controller consists of static semiconductor switches operated by a transistor-type pulse-generator. The switches are connected in the battery circuit, which is turned on and off very rapidly. The on time (pulse width), or the off time (pulse spacing), or both, are varied smoothly by depressing the accelerator pedal, thereby controlling the average power transmitted to the motor. With these controllers the acceleration is exceptionally smooth, and very low constant speeds can be maintained. Between the pulses of current in the discharge direction, short inductive pulses of energy are injected into the battery in the charge direction, and this may be detrimental to battery life. Until further experience of battery life is obtained the power magnitude of the charge pulse is being restricted to 5 per cent of the adjacent discharge pulse by limiting diodes.

Human Factors in Telephony

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Human factors are becoming increasingly important as communication systems become more complex, and the range of problems that occur and the effort being devoted to their solution are briefly reviewed. A typical problem—that of telephone-dial design—is discussed in more detail.

INTRODUCTION

HUMAN-FACTORS problems are liable to arise whenever there has to be an interchange of information across the interface between a man and a machine: for example, when a subscriber has to operate a telephone dial to obtain a required connexion on an automatic telephone system. The question then arises whether the procedure he has to follow is as simple as it is possible to make it. For example: Could the telephone dial be improved so that the public could dial more quickly and make fewer errors? Could the dialling of long sequences of digits be made easier by breaking the number up into groups? Could anything be done to make the various "tones" easier to recognize?, and so on. The increasing awareness by telephone administrations of the importance of the human factor as communication systems become more complex is exemplified by the large number of papers presented at the third International Symposium on Human Factors in Telephony, held at The Hague in June 1966. Specifically limited to telephony, the subjects discussed ranged from subscriber dialling of international calls to the acceptability of long-delay transmission circuits via satellites.

In every new project involving mechanization or automation, human factors are involved in both the policy-making and the technical stages of the work, and must be regarded as integral elements in any decision-taking process. The prime responsibility for taking due note of the human-factors aspects of any activity must rest with that part of the administration concerned with promoting the activity in question, but cases are bound to occur where advice and assistance are needed from specialists, or where existing knowledge is inadequate and new research is necessary.

HUMAN FACTORS RESEARCH COMMITTEE

To meet the needs of the Post Office, a central Human Factors Research Committee has been set up, under the Chairmanship of the Director of Research, with wide representation drawn from administrative, operational and engineering interests—including the Inland Telecommunications Department, the External Telecommunications Executive, the Postal Services Department, the Buildings and Welfare Department, the Statistics and Business Research Department, and the Engineering Department.

The functions of the committee are to promote a general awareness of the importance of human factors throughout the system, to make specialist advice available where it is needed, to initiate basic studies in areas where ignorance exists, and to co-ordinate activities to avoid overlapping. The committee does not carry out research work directly, and there is no central experimental unit purely for human-factors research within the Post Office. Studies related to specific applications are carried out by teams already concerned with other aspects of the activity or service involved. Help in the relevant specialized fields of applied psychology, physiology and ergonomics is available from the Applied Psychology Research Unit of the Medical Research Council. The Deputy Director of this unit, Dr. R. Conrad, acts as honorary consultant to the Post Office. Specialist advice on other relevant topics, such as statistics, is already available from within the resources of the Post Office. Independent consultants and commercial firms may be called upon as required: for example, in conducting opinion-poll or market-research types of survey.

There are, of course, some arguments in favour of having a central human-factors research body within an establishment such as the Post Office, but, unless it can be rather large, there are difficulties in staffing it so that it includes the range of skills and experience required to give due weight to applications aspects of its problems. The type of organization described above has the important advantage that the people involved are experts on the service concerned, and also have a strong vested interest in seeing that it operates as efficiently and effectively as possible. They are in a good position to resolve the conflicts that inevitably arise between human-factors and technical or economic considerations, and to know where adjustments or relaxations can best be made.

On the other hand, there is undoubtedly a need for some studies of basic human capabilities, and of adaptation to particular environments, not tied to specific services or applications. Here the need for skills in applied psychology and in the techniques of human experimentation are dominant. The Applied Psychology Research Unit of the Medical Research Council is not only very well equipped but is also interested in this field, and close co-operation is maintained between it and the Post Office.

Acceptance of Advice

It is a characteristic of human beings with a job to do, usually with a date attached to it and with insufficient money resources, that they often resent "interference." If an outside expert is to help or advise he must be accepted by the people working on the problem and have free access to all the information that might bear on his judgment. Persuasion, not co-operation by decree, is thus called for. The most powerful advocate is example, and instances where timely consultation on human-factors aspects has brought manifest advantages are helping to convince the sceptics. A small "rogues' gallery" is being collected at the same time: it includes such items as the streamlined telephone exchange switchboard with a shiny convex top which, from every possible position, presented the operator with a glaring bright line image of a fluorescent light fitting.

†Post Office Research Station.

The organization described above has been built up over the years, but, since the formation of the Human Factors Research Committee 3 years ago to provide a focus, there has been evidence among engineers and administrators of increasing concern with, and awareness of, human-factors problems, and the committee has been successful in bringing interested parties together with mutually beneficial results.

Ergonomics Problems

The design of equipment such as switchboard positions, control consoles, etc., at which people have to work, constitutes a class of problem involving ergonomics which recurs again and again. It appears in relation to telephones, telegraphs, radio and postal work. It affects not only the staff, but also, at times, members of the public.

A valuable body of experience on design factors such as working heights, comfortable reach, lighting and display layouts is being accumulated, and can be made available to new projects. This is a field in which successful ventures are already stimulating new requests for advice.

Other ergonomic problems that have been dealt with include the design of dials and push-button layouts for subscribers' instruments. Current studies of this kind include the design of public call-offices, and filing systems to give operators at inquiry positions easy access to very large blocks of information.

Psychometry

Another common class of problems concerns the subjective reactions of the users of a communication service to some defect or oddity in the sensory experience provided. Examples are the effect of sidetone on the level of telephone speech, and the effect on 2-way conversation of long propagation delays such as might be experienced over satellite communications links.* Experimental work on the subjective effects of noise and of distortion of various types on communication systems is in progress almost continuously. The somewhat unusual distortions introduced by analysis-synthesis telephony systems, and by the methods of transmission such as pulse-code modulation that involve quantization of the amplitudes of a signal, have been under study. Bordering on the field of aesthetics is current work on the characteristics of tone-calling devices to replace the traditional bell in the telephone set. An extension of this work into the visual field, with investigations of the acceptable levels of impairments in black-and-white and colour television pictures, probably also has some elements in this category.

Most of the work described above is still sufficiently closely related to specific services or systems to be best carried out by the teams responsible for them. In fact, the greater part of the laboratory experimentation is done at the Post Office Engineering Department's Research Station at Dollis Hill, but by the normal engineering and scientific staff and not by specialist applied pyschologists. The Research Station does, however, have at its disposal experts in acoustics (including the characteristics of speech and hearing), in statistics and in experimental design, with adequate supporting laboratory facilities for subjective assessment studies, and an organization for the supply of volunteer subjects. The study of methods of rating communication systems, and of assessing users' performance over them, has indeed been a speciality for some years.

Field Studies

Many of the studies described above involve observations in the field as well as laboratory experiments, and indeed there are many questions which can only be answered by seeing how the public at large reacts while going about its everyday business. The design of an apparently simple device, such as a telephone handset, offers an example: shortening the handle by 0·5 cm may bring the transmitter nearer to the lips and give a useful increase in output, but shortening it by 1 cm may result in the average user having to drop the mouthpiece below his chin, with a consequent loss of perhaps 20 dB.

Valuable assistance in many fields is afforded by the Regions. For example, in the development of the 700-type telephone for the 1,000-ohm line, the design team needed to know the probable reaction of the user to the increased loudness which this more sensitive set would provide. With the co-operation of the then Home Counties Region, all the telephone extensions in the Telephone Managers' Offices at Canterbury and Portsmouth were equipped with prototypes of the new telephone, and after a month's trial all the users were asked for their comments. Analysis of the responses showed clearly that the reception on local calls was too loud, and it was as the result of this trial that the Engineer-in-Chief made the decision that a regulator would be necessary to reduce the sensitivity of the set on short lines.

Regional assistance is currently being given in other fields, such as in a survey of the difficulties encountered in call-offices by infrequent users of the telephone. Design of equipment such as the time assignment speech interpolation (T.A.S.I.) system for use on transatlantic cables also requires detailed knowledge of the telephone conversation habits of the public. Changes in the trunk-call charging structure consequent on the introduction of nation-wide and international subscriber dialling react on call-holding times, and, hence, directly on the targets for provision of equipment in exchanges. Information for many purposes such as these has to be collected in the field.

Man-Machine Interaction

The increasing complexity of the communication network raises problems, the solution of which demands close co-operation between the communication experts and the human-factors specialists.

Press-buttons in place of the dial on the subscribers' instrument appear to be attractive. With the spread of more-modern switching systems they will permit faster signalling. For the moment, however, the bulk of the British automatic telephone network is tied to step-by-step signalling. If press-button telephones are installed, storage devices are necessary at the exchange to absorb any speed difference. Laboratory studies on the speed of operation have given essential information for the economic design of such buffer stores, and will also be relevant to the design of superseding high-speed signalling equipment.

The introduction of all-figure-numbering schemes will

*Hutter, J. Customer Response to Telephone Circuits Routed via a Synchronous-Orbit Satellite. (In this issue of the *P.O.E.E.J.*)

bring a whole series of human-factors problems in its wake. Laboratory studies are necessary at the basic level to determine whether people can remember the long strings of digits and signal them with an acceptably-low frequency of errors, and, as a corollary, there is a need to find out the best way of recording and presenting both the numbers themselves and the rather complicated operating instructions likely to be involved, especially during the change-over period. Greater consideration may have to be given to mechanical aids such as repertory diallers, or to short-code dialling facilities from exchanges. Special engineering provision may have to be made to minimize the complications arising from the co-existence of old and new operating procedures for different destinations, especially for exchanges on the fringe of an area undergoing conversion.

Long-Term Study

The examples in the preceding paragraph lead to consideration of a long-term aim for human-factors research in the Post Office. Taking telephone service alone, the depth of penetration into households in the United Kingdom amounts to some 22 per cent. The demand is growing fast, but it is possible that there are some aspects of the telephone "machine" which a substantial fraction of the public finds difficulty in coming to terms with. An early investigation seems desirable in view of the difficulty and cost of making any retrospective changes in the telephone system.

A plan is, therefore, being formulated for an overall look at the service from the point of view of its compatibility with the basic capabilities of the ordinary member of the public. In this connexion the fact that the public includes non-users and infrequent users should not be forgotten: the majority of operational studies have been of telephone usage, and most surveys have been of subscribers.

The whole question of ease and convenience of operation (including the problems mentioned previously of length of digit trains and of non-uniformity of procedures), the distinguishability of tones, and the intelligibility of instructions, needs to be reconsidered. Side by side with this there must be detailed surveys of telephone attitudes and habits, including those of the infrequent and inexperienced user. Since an unsuccessful user may often not know where or how things went wrong, such an opinion survey must be backed up by detailed analyses of service and traffic records to extract information about the nature of misoperation, incidence of congestion, misunderstanding of operating instructions and of tones, and so on.

Even on a national scale, such a plan is likely to call for a considerable effort on the part of specialized laboratories for experimental studies, from operating authorities for collecting and analysing service data, and finally from the planning and engineering authorities in devising ways of putting the findings into effect. It will be apparent that such studies should not stop at national boundaries, and that at some point they are likely to impinge on international planning and standardization bodies. On the other hand, international traffic, though growing fast, will always represent a small fraction of the total.

Other Fields

Though strictly beyond the scope of this article, there are many fields outside telephony in which the Human Factors Research Committee of the Post Office finds itself involved. Many of these generate problems with a familiar ring. Ergonomics are involved in the design of machinery for automatic handling of mail, from conveyors to coding desks. The postal side also poses questions on the design of area and street codes to be used by the public as well as by sorters. The Post Office banking activities and its part in the national savings movements are equally likely to raise human-factors problems, some of which will have already been solved in the communications field. The Human Factors Research Committee organization is wide enough to include these diverse activities, as well as those relating to telephony, and may well stimulate cross-fertilization of ideas and help to avoid duplication.

A TYPICAL EXPERIMENT—FACTORS IN TELEPHONE-DIAL DESIGN AFFECTING SUBSCRIBERS' DIALLING ERRORS

A good example of a human-factors experiment carried out in the laboratory with a panel of volunteer "subjects" is the recent study of the factors in the design of telephone dials which affect subscribers' dialling errors. This was undertaken because service observations showed that subscribers were, in general, making more dialling errors on the 700-type telephone than on the older 300-type set. There are several physical differences in the two dials, the main differences being as follows.

(*i*) The dial was mounted at 40° to the horizontal in the old set, and at 30° in the new.

(*ii*) The dial finger-plate was made of thin stainless steel in the old set, and of thick opaque coloured plastic (and, at a later stage, of transparent colourless plastic) in the new set.

(*iii*) In the old set, the letters and the numbers were seen through the finger holes; in the new set, they were displayed on a fixed outer number ring.

A series of laboratory experiments was conducted, in each of which a sample of more than 100 telephone users dialled sequences of London exchange numbers under observed conditions.

The first series of tests, made in 1962–3, confirmed that the errors on the new telephone were just twice those on the old set. Further tests in 1964–5 then showed that neither the altered slope of the dial mounting, nor the thickness or material of the finger plate, played any significant part in the results. The superiority of the old dial appeared to be due entirely to the different way in which the letters and numerals were displayed.

At this time there were other reasons for not wishing to abandon the outer number ring, and further experiments were made with modified arrangements of the numerals and letters. It was observed that most of the dialling errors occurred in the four numerals rather than in the three initial letters of the exchange code, and it was established that, provided the numerals were displayed within the finger holes, it did not make very much difference whether the letters were displayed also within the finger holes, or separately on the outer ring. Of course, with the introduction of all-figure numbering, the position of the letters now becomes only an academic point.

The Dialling Tests

The objective in each test was to simulate normal conditions of dialling, and to record the errors made by the subjects using the various dials under comparison. The immediate difficulty under laboratory conditions is that, in a straightforward task of dialling given numbers under observation, the subjects make extremely few errors, and it immediately becomes evident that some method of stressing or distracting the subject is required, to prevent him giving his full undivided attention to the task of dialling. Normally, the subscriber has his mind occupied with other matters—perhaps remembering a number which he had just been told, or deciding what he is going to say when the respondent answers—and stressing the subject in the laboratory test therefore serves the double aim of making the test more realistic and of producing more errors.

The method adopted throughout these experiments has been to make the subject remember the number which he is about to dial. Initially, the 7-digit London number (three letters, followed by four numerals) to be dialled is displayed by projection on a small screen in front of the subject. He is allowed to study this number as long as he wishes, but the instant he starts to dial, the display is switched off. Obviously, some number sequences are more easily remembered than others, but in a fairly large-scale experiment it can be arranged that all the blocks of numbers to be dialled appear an equal number of times with each of the dials used in the test, and the overall results of the tests do indicate that the errors made by the subjects are related to the difficulty of using the dial.

Altogether, five large-scale experiments have been conducted, three at Shoreditch telephone exchange using trainee telephone operators (mostly teenage girls, straight from school), and two at Dollis Hill using the Research Station staff in general (of all ranks and ages, but mostly male). Each experiment used between 120 and 140 subjects, and each subject dialled at each sitting a total of 40 7-digit numbers, 10 on each of four different dials. These figures are mentioned to indicate the size and cost of this type of human-factors experiment. In these particular experiments the error rates showed large variations, and it was only by including such a large number of observations that it became possible to obtain meaningful results.

Typical Dialling Experiment

A typical dialling experiment (Dollis Hill, Test II, 1964) was one designed to evaluate the effect of the outer number ring. Four different dials, types E, F, I and J (Fig. 1), were compared; in all the tests the dials were mounted on the standard black typc-706 telephone. Dial E will be recognized as the present standard British Post Office dial. On dial F the letters and numbers have been placed within the finger holes, and the outer ring has been left blank. Dials I and J represent compromises between these two extremes.

On entering the test cabinet, the subject was seated at a table and handed a telephone, which he was told to place anywhere he pleased on the table, except on top of a blotting pad immediately in front of him. The first 7-digit number was then projected on the screen, and he

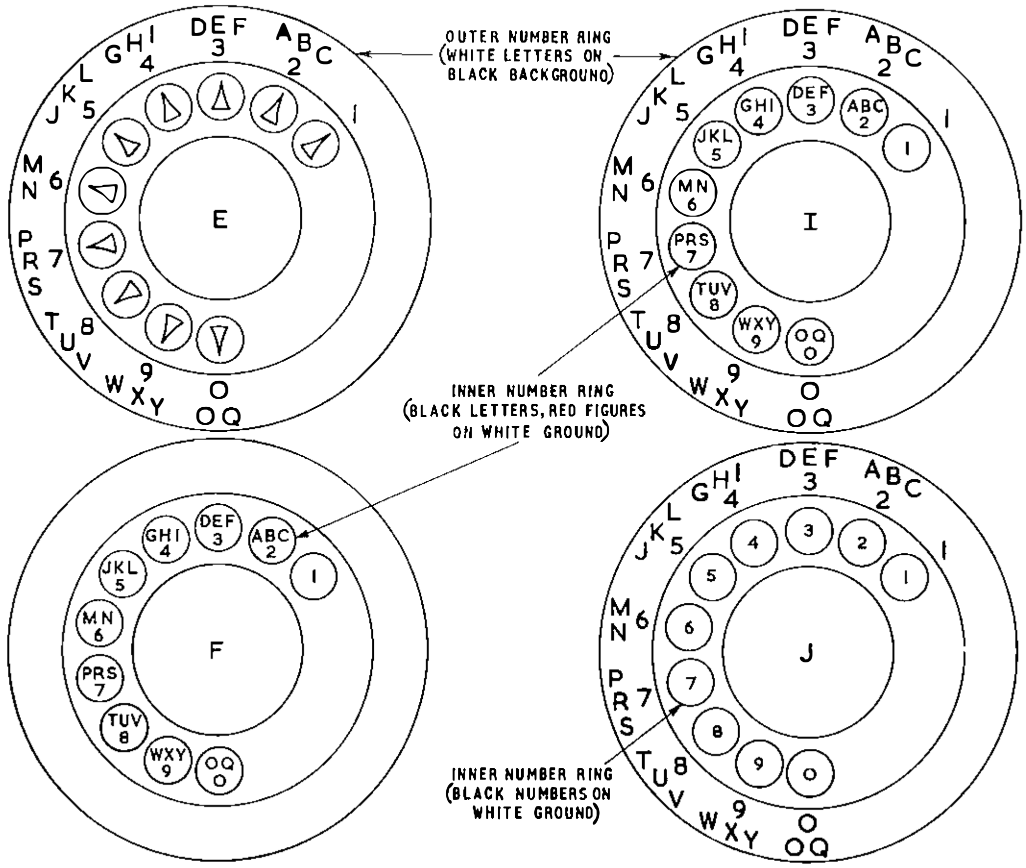


FIG. 1—TYPES OF DIAL COMPARED IN DIALLING TEST (DOLLIS HILL, TEST II, 1964)

commenced to dial. After dialling a block of 10 London numbers, he was given a second telephone, and asked to dial a second block of 10 numbers. This procedure continued with a third and fourth telephone, the whole sitting taking about 20 minutes and involving the dialling of 280 digits. It was noted that, generally, the subject made most of his errors in the first block (while the test procedure was still strange to him), and in the last block (when fatigue was setting in). The order in which the four telephones were presented to the subjects was of course rotated from sitting to sitting.

A total of 120 Post Office personnel participated in the experiment. To even out the effect of small mechanical differences in the dials, five samples of each dial type were used; altogether, there were 20 telephones which will be referred to as E1, E2, E3, E4, E5; F1, F2 .... and so on. Of the 120 personnel 24 used telephones E1, F1, I1, J1, another 24 used telephones E2, F2, I2, J2, and so on. Twenty-four blocks of 10 7-digit London telephone numbers were used, each block appearing an equal number of times in each of the five groups of like-numbered telephones, thus improving the validity of comparison between the five sections of the experiment denoted by the sample numbers. Within each of five sections, the experiment was balanced as regards blocks of numbers and order in which the four telephone types were offered to the subject, all possible permutations occurring equally.

On the basis of total errors, telephones J and F appeared to be the best, and telephones E and I the worst, but the differences in error rates were not significant statistically. The spread of the results is illustrated even more clearly in Fig. 2 by considering the test as composed of five sections, corresponding to the five groups of telephone specimens: E1, F1, I1 and J1, to E5, F5, I5 and J5. Within each section, the experiment is balanced, and, hence, it is possible to consider each section separately. The variations between the five sections are an indication of the statistical significance obtained in relation to the size of the test.

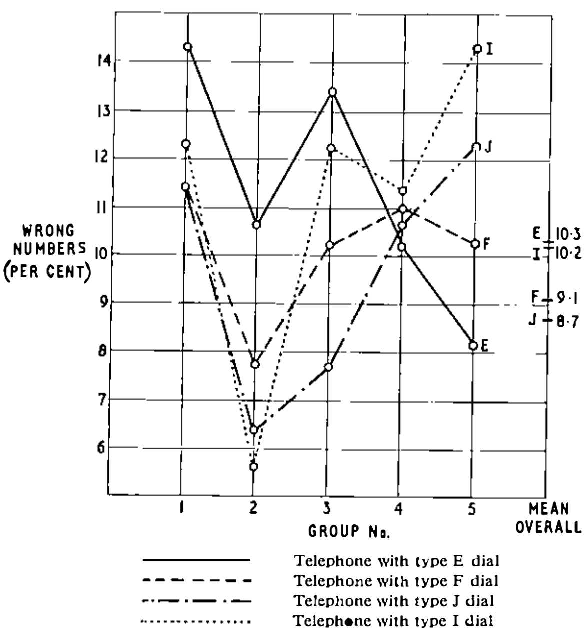


FIG. 2—COMPARISON OF ERROR RATES FOR FIVE DIFFERENT GROUPS OF SUBJECTS

In all these tests the dialling time, i.e. the total time elapsing between the first movement of the dial and the completion of the 7-digit sequence, was recorded, and it is noteworthy that the dialling times throughout showed much smaller variations than the error counts. The dialling time for type E (see Fig. 3) exceeds the overall mean by an amount which is very highly significant (the probability of this difference occurring by pure chance being less than 0·1 per cent). The dialling time for type

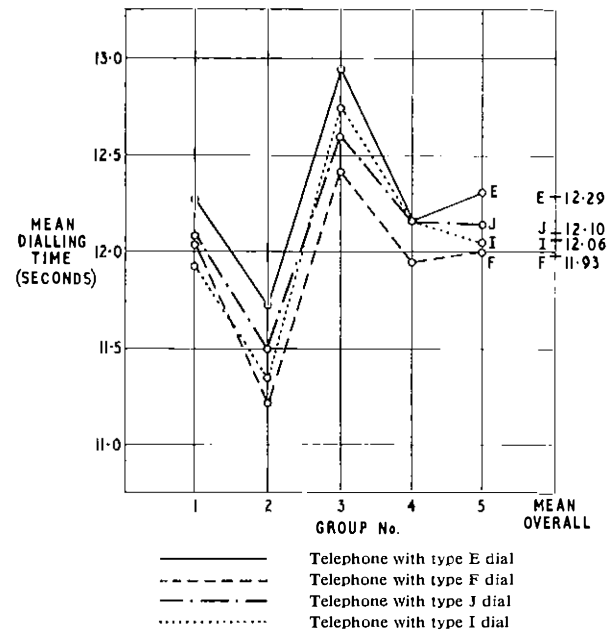


FIG. 3—COMPARISON OF DIALLING TIMES FOR FIVE DIFFERENT GROUPS OF SUBJECTS

F is less than the overall mean by an amount which is highly significant (chance level less than 1 per cent).

Thus, if dialling time can be taken as the criterion instead of error rate, it can be stated with confidence that telephones I and J are inferior to telephone F but superior to telephone E. The greater consistency of dialling-time measurements is evident in Fig. 3.

However, although the assessment of dial performance on the basis of dialling time would be much easier than on the basis of error rate, there are obvious dangers in this: it is conceivable that a dial might be designed which gave rise to very few errors and yet was slow to use—and vice versa. It is probably only safe to rely on dialling time alone as a measure of goodness when comparing dials of similar type and performance.

Examples of Learning Effect

During the course of these investigations, covering a period of 3 years (1962–1965), a gradual decrease in the difference in error rate between the new and old telephone sets (retained in successive experiments as controls) was observed. A fresh batch of subjects had been used for each experiment, and the only explanation for the decline would seem to be the increasing familiarity of the public with the new dial: whereas in 1962 many of the subjects were meeting the new dial for the first time, by 1964–5 it had become as familiar as the old dial.

Because of the artificial nature of the environmental conditions and stressing of the subjects, it is, of course, not valid to make comparisons between the absolute values of error rate from one experiment to another, and it should not be concluded from the following table that the overall error rate has necessarily worsened with succeeding years. It is the ratio of the errors on the two telephones within each experiment which is of interest. It will be noted that the change in ratio of errors between the two telephones has not been matched by a similar change in ratio of dialling times.

Dialling Test Using 300-Type and 700-Type Telephones

Experiment	Subjects	Wrong Numbers (Per Cent)		Mean Dialling Time (Seconds)	
		300-type Telephone	700-type Telephone	300-type Telephone	700-type Telephone
Service Observations (1962)		2·2	5·7	—	—
Shoreditch Test I (1962)	140 trainee operators (young, 90 per cent female)	7·9	15·2	11·76	12·31
Dollis Hill Test I (1963)	120 mixed Post Office staff (average age 37, 85 per cent male)	8·7	11·0	11·75	12·40
Shoreditch Test III (1964–5)	120 trainee operators (average age 26, 90 per cent female)	11·5	12·7	11·44	12·00

The foregoing illustrates a major difficulty in conducting any human-factors experiment in which something new and unfamiliar is to be compared with an established and familiar item. Unless a protracted period of "learning" is allowed on the new item, comparisons can be misleading.

An example of an experiment designed to allow for a learning effect is that carried out to assess the probable performance of a dial having a novel type of finger plate with open-ended spokes instead of finger holes. A small group of subjects repeatedly performed a task of dialling blocks of numbers alternatively on the standard and the experimental dial, and after each day's session the average dialling times for the two dials were compared. As the experiment proceeded, the times became progressively shorter, but the standard dial continued to maintain its superiority over the experimental dial (Fig. 4).

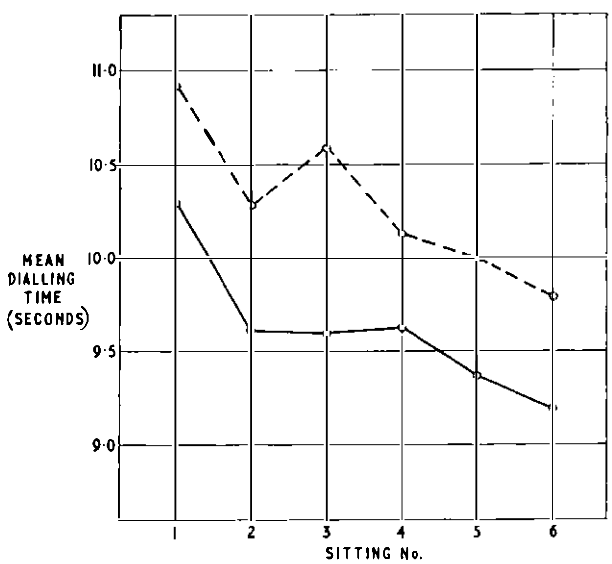


FIG. 4—EXAMPLE OF LEARNING EFFECT, SHOWING THE TENDENCY FOR DIALLING TIME TO DECREASE WITH EXPERIENCE

Pitfalls in Analysing Results

This account would be incomplete without some mention of the pitfalls encountered. In order to facilitate processing of the results of the dialling experiments, the numbers actually dialled by the subjects were recorded on punched tape, and arrangements were made for the subsequent analysis of errors to be done by computer. However, when the first analysis showed an unexpectedly high error rate, a more detailed scrutiny of the error sheets revealed that many of the errors recorded were not legitimate dialling errors at all. For example, on more than one occasion the wrong block of 10 slides had been inserted in the projector by mistake. This was not spotted by the computer, which merely logged up 70 incorrect digits. Again, a nervous subject sometimes started to dial the first digit, realized that he or she was making an error, and started again, this time dialling the seven numbers correctly. But the machine had already recorded the first digit, and so a total of seven errors was clocked up.

Analysis of the results of the second experiment showed a large number of "minus-one" errors (in which the subject appeared to have dialled, for example, six instead of seven) and this remained a mystery until a further analysis of the results showed that the likelihood of a minus-one error occurring seemed to be directly related to the numerical value of the digit dialled. This immediately threw suspicion on to the electronic equipment responsible for recording the dial pulses, and it was then confirmed that, when the dial speed and the make-to-break ratio were within a critical range, an occasional "dial pulse missed" was being recorded.

The conclusion was reached that it is unwise to rely too much on mechanized recording and analysis, and that there is no real substitute for a detailed and painstaking scrutiny of the individual error sheets.

ACKNOWLEDGEMENTS

It is a pleasure to acknowledge the major part that Dr. Conrad of the Applied Psychology Research Unit of the Medical Research Council has played in many of the ergonomic problems studied.

Acknowledgement is also made to the authors' colleagues Mr. R. R. Walker and Mr. A. H. Ithell for the experimental results quoted in the telephone-dial design dialling test.

Drying Out Joints in Paper-Core Cables

U.D.C. 621.315.68:66.047

The difficulty of ensuring that the silica gel used for drying out joints is thoroughly dry before being placed within the joint has been overcome by the packaging of the silica gel in a new way. The need for the use of heat is entirely avoided, saving time and avoiding the risk of damage to polythene-sheathed cables.

FOR many years British Post Office engineering instructions have stated that joints in paper-core local cables should be dried out by means of silica gel enclosed within the joint sleeves, without the assistance of any form of heating. The method, which is basically sound, was introduced largely as an economy measure to make unnecessary the unproductive hours spent on drying out joints using the heat from blow lamps; it may take as long as 2 hours to dry out a joint in a large cable. It is known, however, that silica gel has not been popular with jointers, many of whom, instead of using silica gel, rely entirely upon heat for drying out their joints, whilst others dry out with heat and then enclose silica gel within the joints. This lack of faith in the efficacy of silica gel is believed to stem from failures which have resulted from the very real difficulty of ensuring that the silica gel, at present inserted into cotton-gauze pockets by the jointer himself on site, is thoroughly dry when it is placed amidst the jointed conductors prior to joint closure.

Laboratory trials on the restoration of high insulation to really damp joints by means of silica gel, purchased in thoroughly-dried form and packaged in an entirely new manner, have shown that the insulation resistance of each conductor rises to at least 500 megohms within an hour of closing the joint, to some 10,000 megohms within 8 hours, and to a much higher insulation figure after a week. The silica gel is packed by the supplier in porous and semi-transparent paper sachets, each of which he then encloses within a moisture-proof envelope made of polythene-backed aluminium-foil, heat sealed at its edges. The jointer is simply required to tear open the specified number of moisture-proof envelopes, withdraw the paper sachets, and enclose them within the joint sleeve immediately prior to commencement of the sleeve-to-cable-sheath closure operation, as shown in the illustration. It has been found unnecessary to place the paper sachets in the midst of the jointed conductors to restore insulation.

The avoidance of naked flames for drying-out purposes in the vicinity of polythene-sheathed cables is an added advantage of the silica-gel method, because polythene has a low melting point and is easily damaged if a flame inadvertently comes into contact with it.

C.P.S.

INSERTING SILICA-GEL SACHET INTO SLEEVE OF CABLE JOINT

Customer Response to Telephone Circuits Routed via a Synchronous-Orbit Satellite

J. HUTTER, B.Sc., C.Eng., M.I.E.E., F.S.S.†

U.D.C. 621.395.4 : 629.783 : 525 : 658.89

This article describes a series of tests carried out during a period of 22 weeks following the provision of public traffic circuits between U.K. and U.S.A. by means of the synchronous-orbit satellite HS-303. A quantitative assessment of the effect on customers of the greater propagation time of these circuits is given.

INTRODUCTION

International telephone circuits can be provided by various means, including submarine-cable schemes and communication satellites at different altitudes. The main difference between such circuits is in propagation time.

The effects of long propagation times are currently being studied by telephone administrations of the world under the auspices of the C.C.I.T.T.* Laboratory tests completed in September 1963 had shown that mean one-way propagation times in excess of 150 ms could cause conversational difficulties, but further investigation was necessary to assess the magnitude of the difficulties likely to be encountered by actual customers.

Between June and November 1965 a series of tests was carried out involving circuits between London and New York routed over the synchronous-orbit communications satellite HS-303 and having a mean one-way propagation time of 270 ms. The test program was designed to determine the answer to two main questions.

(*i*) Are customers who frequently make calls over a mixture of synchronous-orbit satellite and cable circuits more likely to notice, and be affected by, the greater propagation time of the satellite circuits than customers who make very few calls over such circuits?

(*ii*) What is the magnitude of any further adverse effects caused by including a synchronous-orbit satellite as one link of an extensive world-wide telephone network?

Part A of the tests, intended to answer question (*i*), necessitated a complete record, obtained from call tickets, of calls originated or received in the United Kingdom, U.S.A. and Canada over a satellite circuit.

Part B investigated customer response to six typical circuit conditions involving various combinations of echo suppressors and 20 ms additional propagation time.

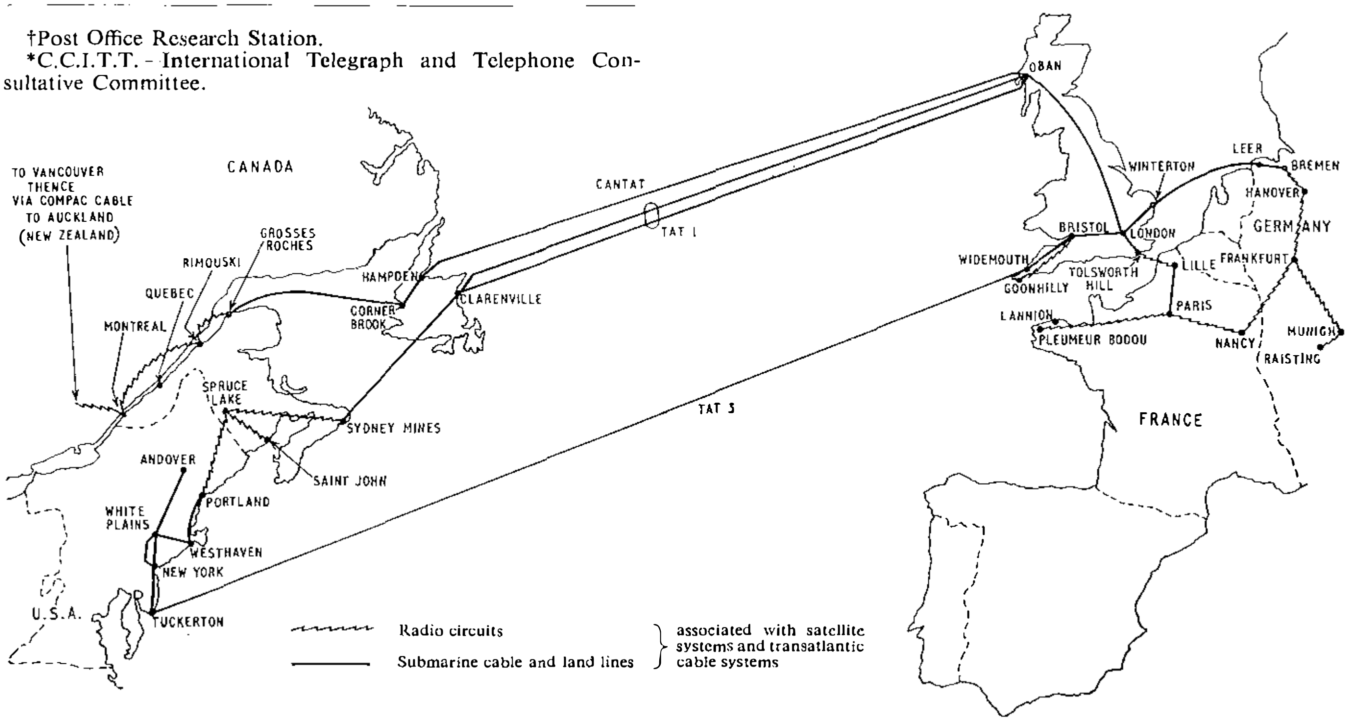
Parts C and D involved circuits having substantial propagation time, representing a synchronous-orbit satellite link extended by a long submarine-cable system. Post Office personnel took part in the Part C tests, permitting the observation of the type and occurrence of difficulties attributable to imperfect transmission.

DESCRIPTION OF CIRCUITS USED IN THE TESTS

The submarine cables linking this country with the U.S.A. have a velocity of propagation of about 120,000

†Post Office Research Station.

*C.C.I.T.T.—International Telegraph and Telephone Consultative Committee.



American satellite earth station (Andover, Maine) linked to European earth stations (Goonhilly, Raisting and Pleumeur Bodou) via HS-303 satellite.

FIG. 1—CABLE ROUTES AND SATELLITE EARTH STATIONS USED IN HS-303 SATELLITE TESTS

TABLE 1

Routing and Propagation Times of Circuits used in Tests

Experiment	Terminals	Routing	Approximate Distance (miles)	Velocity of Propagation (miles/second)	Mean One-Way Propagation Time, Including Land Lines (ms)
Part A T.A.S.I.	London–New York	TAT-1, TAT-3, or CANTAT	4,000	120,000	35
Parts A, B and D	London–New York	Satellite HS-303	47,000	186,000	270 (with additional 150 ms delay in Part D tests = 470 ms)
Part C	London–Auckland (New Zealand)	Satellite HS-303, microwave link across Canada, and COMPAC cable	56,000	Composite satellite and cable route	350

miles per second, and the mean one-way propagation time encountered on a typical cable connexion, for example between London and New York, is about 35 ms. The corresponding propagation time for a similar call routed over a synchronous-orbit satellite link is about 270 ms: for such a link, although the velocity of propagation is approximately 186,000 miles per second, the total distance between ground stations, via the satellite, is about 47,000 miles.

Fig. 1 and Table 1 show the submarine-cable routes and associated national extensions used in the tests, and the location of the four satellite earth stations, i.e. Andover (Maine, U.S.A.), Goonhilly (United Kingdom), Pleumeur Bodou (France) and Raisting (West Germany). All the European stations were used in rotation for routing satellite calls between the United Kingdom and U.S.A.

OBSERVATION METHODS

Information on the performance of telephone connexions was obtained by a number of methods, described below.

Customer Interview

In those parts of the tests involving public traffic it was not possible to monitor or record conversations, and so the required information on circuit performance was obtained by interview. Shortly after the conclusion of a call, the customer was rung by an interviewer who possessed details of the call but not of the circuit over which it had been routed. Questions posed to the customer by the interviewer included the following.

"Did you, or the person who spoke to you, have any difficulty in talking over that connexion?" (Yes or No).

"Which of the following words comes closest to describing the quality of that connexion: excellent, good, fair or poor?"

Other slightly less important questions related to the quality of the customer's usual calls to the U.S.A. (if applicable), the number of calls made per month, and a request for comments about the overseas telephone service.

"Percentage difficulty" is defined as the percentage of calls after which the customer or subject indicated that he had experienced difficulty.

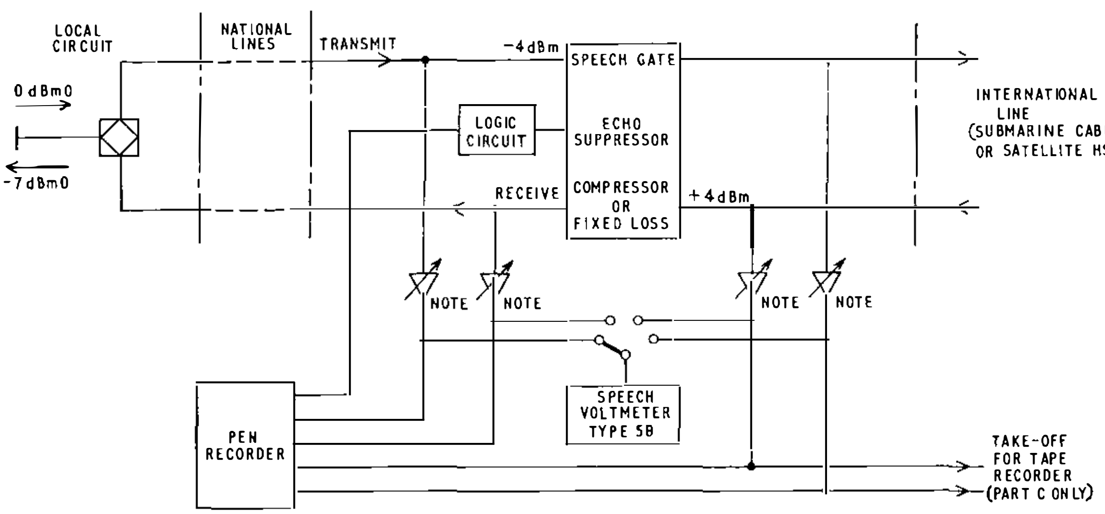
Numerical scores of 4, 3, 2 and 1, respectively, were allocated to the four categories used in replying to the second question. Averaging over all the results for a particular test condition gives the mean opinion score. "Percentage poor or fair" indicates the percentage of calls after which the customer expressed either of these opinions in reply to the second question.

Monitoring

Direct monitoring of the line conversations is not very satisfactory even when considerations of privacy permit. For this reason recordings were made in the part of the tests that did not involve public traffic, to facilitate examination of conversations. The recordings were replayed to several trained monitoring observers who noted the incidence of difficulties, double-talks and confused situations.

Speech-Volume Measurements

On some connexions the volume of both incoming and outgoing speech was measured using a Speech Voltmeter Type 5B[1] connected to a 4-wire point in the circuit, with suitable adjustment made to refer the results to the zero-



Note: High-input-impedance amplifier-attenuators to minimize tapping loss and adjust all pen-recorder track inputs to same level.

FIG. 2—CONNEXIONS OF TAPE RECORDER, SPEECH VOLTMETER AND PEN RECORDER

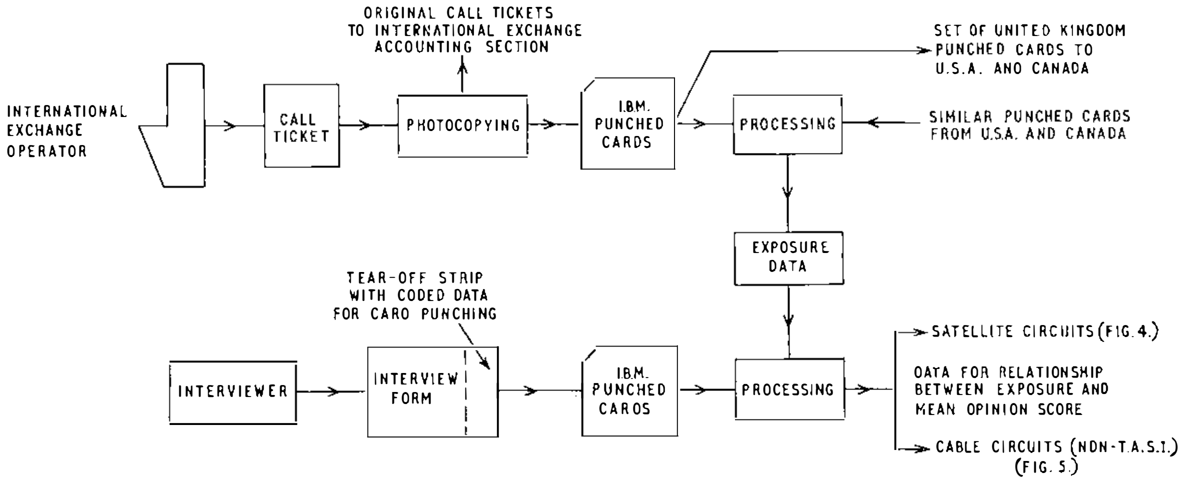


FIG. 3—DETERMINATION OF EXPOSURE (PART A TESTS)

level points. In one instance the observations enabled a circuit, which had been lined up incorrectly, to be identified and the corresponding results discarded.

Pen Recordings

The presence of echo due to poor return loss, and double-talks in conversation, was shown by the traces produced by pen recorders associated with several of the circuits used in the tests. Four of the five recorder inputs were connected to the four ports of the echo suppressor, giving traces which indicated roughly the speech envelope existing at these points; the fifth indicated the particular state assumed by the echo suppressor at each instant.

The points in the connexion to which the tape recorder, speech voltmeter and pen recorder were attached are shown in Fig. 2.

DESCRIPTION OF TESTS

The four parts into which the tests were divided were as follows:

Part A—calls between the London Director Area and New York (NPA212*) involving the satellite link, and also, during the latter half of the experiment, a small number of circuits not routed via T.A.S.I.[2] equipment (non-T.A.S.I. circuits).

Part B—calls between United Kingdom provincial customers and U.S.A. customers in 21 NPAs excluding New York.

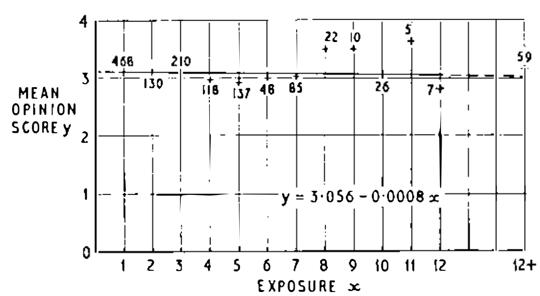
Part C—test calls between London and New Zealand, via the satellite link, Montreal, Vancouver and the COMPAC cable.

Part D—calls between the London Director Area and New York City via the satellite and with added artificial delay of 150 ms.

Part A

Part A of the tests was primarily directed at determining the effects of "exposure"† of a customer. This entailed keeping a complete record, from call tickets, of all customers in the United Kingdom, U.S.A. and Canada who made or received calls over a satellite circuit. The information was treated as shown in the flow diagram, Fig. 3. Call tickets, prepared by the international-exchange operator, were intercepted and photocopied before their normal dispatch to the accounting section. The call particulars, including names and telephone numbers of both parties, date, time and duration of call, were extracted from the photocopy and transferred to IBM punched cards. A similar operation was carried out in the U.S.A. and Canada, and sets of punched cards were exchanged between these countries. In all, some 30,000 punched cards were involved over the 22-week period, and from their processing it was possible to ascertain how many calls, over a satellite circuit, any particular customer had made.

The customer's opinion of the circuit, obtained subsequently by interview, was also transferred to punched cards. Interviewing was, however, deferred until week 9 in order to allow customer exposure to accrue and to avoid premature interviews of potential high-exposure customers. During weeks 9 to 12 as many as possible of the customers who had made over seven calls, together with low-exposure customers (one to three calls), were interviewed. From week 13 the medium-exposure category (four to seven calls) was included.



Notes: 1. Numbers against each point give the number of interviews on which the point is based.

2. The mean opinion scores for more than 12 exposures have not been used in fitting the regression line.

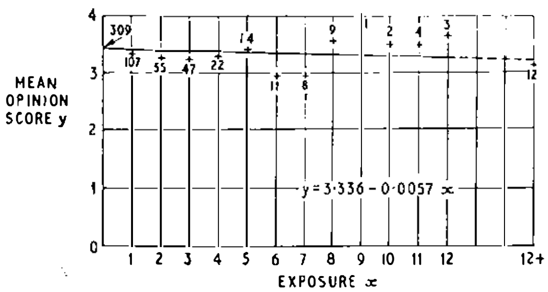
FIG. 4—RESULTS OF INTERVIEW AFTER CALL ON SATELLITE CIRCUIT (UNITED KINGDOM TO U.S.A.)

*NPA—Numbering plan area. In Part B, 21 numbering plan areas were involved (excluding New York City) within a 500-mile radius of New York.

†Exposure in this context is defined as the number of times that the customer had participated in a telephone call over a satellite circuit (including the present call, if it involved a satellite connexion).

From association of the information on the cards, it was possible to classify groups of customers into exposure categories, together with their mean opinion scores. The resulting regression line, shown in Fig. 4 for the results of interview after a call on a satellite circuit, indicates that increased exposure to calls over satellite circuits does not affect to any appreciable extent the opinions which customers express on being interviewed after a satellite call.

Similar information was produced in respect of calls made over the non-T.A.S.I. cable circuits, and, as shown in Fig. 5, the results of interview after a call on a cable circuit produce opinions which are substantially unaffected by previous exposure to the satellite.



Notes: 1. Numbers against each point give the number of interviews on which the point is based.
2. The mean opinion scores for more than 12 exposures have not been used in fitting the regression line.

FIG. 5—RESULTS OF INTERVIEW AFTER CALL ON NON-T.A.S.I. CABLE CIRCUIT (UNITED KINGDOM TO U.S.A.)

The results of Part A tests are given in Table 2. Statistical analysis shows that by all criteria the satellite-circuit performance is significantly worse than that of non-T.A.S.I. cable circuits. Results have also been plotted, with those from other parts of the tests, on Fig. 6, 7 and 8.

TABLE 2

Results of Part A Tests

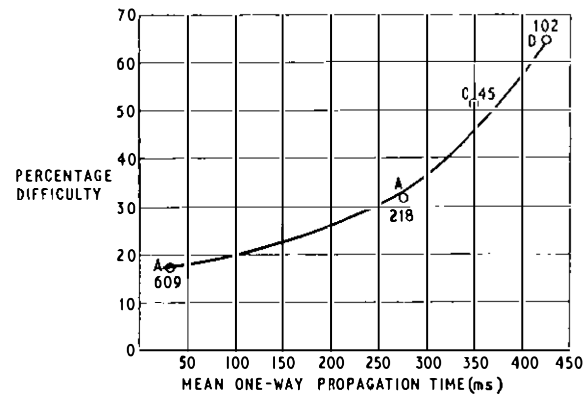
Customer Opinions from Interviews after	No. of Calls	Mean Opinion Score	Percentage Difficulty	Percentage Poor or Fair
Satellite call	218	3·07	33·0	19·7
Cable call (non-T.A.S.I.)	609	3·32	16·6	10·1

Part A Supplementary Tests. During a period of nine weeks, about 350 low-exposure customers in the London director area were interviewed after completing a call to New York City (NPA 212) over a cable circuit involving T.A.S.I. As most cable calls between the United Kingdom and U.S.A. are passed via T.A.S.I. equipment, the conditions are representative of the normal trans-Atlantic service prior to the introduction of satellite working. The results of interviews with these customers were compared with those obtained in the main part of the test for non-T.A.S.I. cable calls made under the same conditions to determine any possible degradation introduced by the T.A.S.I. equipment. Statistical analysis indicates that differences between these results are small and are not statistically significant.

Part B

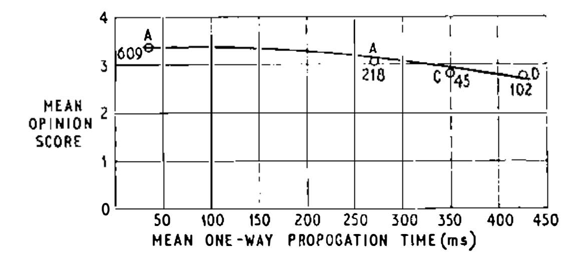
The primary object of the Part B tests was to determine the effects of different types of echo suppressor and of moderate-length 4-wire extensions of the satellite circuit. Six circuit conditions were set up, and these, together with the resulting mean opinion scores, percentage difficulty and percentage fair or poor opinion are shown in Table 3.

There are slight differences in the results for the six circuit conditions, but analysis has shown them to be not statistically significant. Although the population of



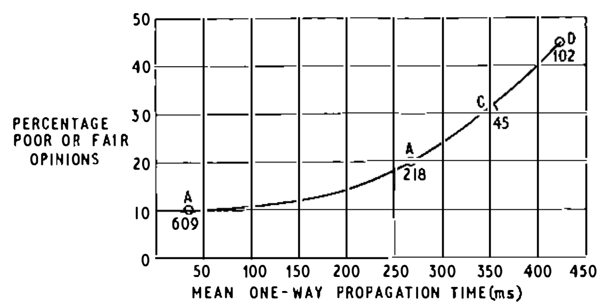
Note: Numbers against each point give number of interviews on which point is based.

FIG. 6—PERCENTAGE DIFFICULTY AS A FUNCTION OF DELAY



Note: Numbers against each point give number of interviews on which pointi s based.

FIG. 7—MEAN OPINION SCORE AS A FUNCTION OF DELAY



Note: Numbers against each point give number of interviews on which point is based.

FIG. 8—PERCENTAGE POOR OR FAIR OPINIONS AS A FUNCTION OF DELAY

TABLE
Results of Part B Tests

Condition	No. of Calls	Echo-Suppressor Type (See Note)		Mean Opinion Score	Percentage Difficulty	Percentage Fair or Poor
		White Plains	London			
1	157	2A	2A	3·09	31·2	19·4
2	166	2A	RC4	3·01	35·0	23·2
3	156	RC4	RC4	3·16	28·2	16·4
4	178	2A with experimental full echo suppressor (zero delay) extension.	2A	2·94	36·5	29·2
5	122	2A	RC4 with full 6A (zero-delay) extension.	3·02	31·2	26·2
6	131	2A	RC4 with full 6A echo suppressor extension including 20 ms delay each way and injected circuit noise (–50dBmOp).	3·04	29·8	21·8

Note: American 2A and British RC4 are new types of echo suppressor specifically designed for long-propagation-time circuits. British 6A is an existing type of echo suppressor currently in use on cable circuits.

customers was different and they were geographically distinct from those used in Part A, the mean results for Part B were very similar, if the comparison is restricted to circuits involving the same type of echo suppressor (see Table 3). Because of these differences, the results have not been included in Fig. 6, 7 and 8‡.

Part C

A single circuit, comprising the satellite link extended via Montreal to Vancouver and thence over the COMPAC cable to Auckland (New Zealand), was used for the Part C tests. The circuit was equipped with echo suppressors Type 2A at each end, with facilities to introduce similar echo suppressors at Montreal, thus giving two circuit conditions, i.e. with and without intermediate echo suppressors. Calls were arranged between Post Office service personnel in the United Kingdom and New Zealand, and each participant was asked to complete a questionnaire giving a statement on difficulty, and his opinion on the same 4-point scale as that used for customer interview.

As this part of the series of tests did not involve public traffic, magnetic-tape recordings were made in London, from a point in the circuit on the line side (send and receive) of the echo suppressor associated with the international circuit, as shown in Fig. 2. These were replayed to independent observers to enable reports on the occurrence of events indicative of imperfect transmission to be assembled. The additional data obtained in this manner have been analysed,[3] and useful information, such as the statistics of the distribution of occurrence of events during a conversation, and coefficients of association between various attributes, has been extracted.

‡Results for the satellite circuit (270 ms mean one-way propagation time) are based upon data from 218 calls. Although considerably more observations were made, it was found, during the conduct of the Part A tests, that one circuit had been incorrectly lined up, and all data relating to calls for which the circuit used could not be positively identified have been excluded from the analysis.

Although the number of observations made was small, the results indicated that there was little difference between the two circuit conditions, i.e. with and without intermediate echo suppressors. The total mean one-way propagation time of the circuit was 350 ms, and the results are plotted in Fig. 6, 7 and 8 (results for both circuit conditions are shown pooled). It will be noticed that these results are consistent with those from the public-traffic parts of the test in spite of the differences in subjects and observation technique.

Part D

A direct satellite connexion was compared with a similar connexion extended via a circuit comprising an additional 150 ms delay introduced by a delay machine, this extension being equipped with its own echo suppressors Type 2A. Customers in the London director area and New York City were used, although the circuits involved were the same as those for Part B.

The results for the two circuits differed to a highly significant extent. The increased propagation time yielded much lower mean opinion scores and markedly increased the percentage of customers expressing difficulty. The total mean one-way propagation time of the circuit, with extension, was 420 ms, and the results are plotted in Fig. 6, 7 and 8.

CONCLUSIONS

The variations with propagation time of percentage difficulty, mean opinion score and percentage poor or fair opinions are shown in Fig. 6, 7 and 8 respectively. From Fig. 6 it will be noted that, even with only 35 ms mean one-way propagation time, 16 per cent of customers reported having some difficulty. This figure was approximately doubled (33 per cent) with 270 ms delay, the curve rising steeply to about 60 per cent at 400 ms.

The percentage poor or fair opinions (Fig. 8) also show a doubling between 35 and 270 ms delay, roughly doubling again from 270 to 400 ms.

From the complete series of experiments, the following conclusions were drawn.

(*a*) There is no evidence that increased exposure to calls over satellite circuits affects the opinions that customers express on being interviewed after a satellite or cable call.

(*b*) Results from interviews after customers have used a cable circuit with T.A.S.I. differ very little (actually to a statistically insignificant extent) from those for cable circuits without T.A.S.I.

(*c*) The results for the synchronous-orbit satellite (270 ms mean one-way propagation time) are significantly worse than those for the cable circuits by each criterion.

(*d*) From that part of the tests in which modest 4-wire extensions were made to the satellite circuits, it may be concluded that the effects of the following are small or negligible.

(*i*) The inclusion of short tandem connexions with or without additional mean one-way propagation time up to about at least 20 ms.

(*ii*) The introduction of intermediate echo suppressors in such connexions, provided that the echo suppressors are of compatible* types.

(*iii*) The use of different echo suppressors at either end of a satellite link, provided they are both designed for use on circuits having long propagation times.

(*e*) There is no significant difference in the results when any one of the three European earth stations is used.

(*f*) When a telephone connexion carried by a satellite is extended over a further 4-wire circuit contributing an additional 150 ms mean one-way propagation time, the subjective performance is further degraded by a substantial amount.

The results, taken as a whole, indicate that circuits provided by means of a synchronous-orbit satellite will give a service generally acceptable to the public provided:

(*a*) not more than one satellite link (270 ms mean one-way propagation time) is included in any connexion, and

(*b*) additional terrestrial links are limited, as far as possible, to those that increase the total propagation time only slightly.

In any case total mean one-way propagation times above 400 ms should be avoided unless no satisfactory alternative is possible.

Detailed results from complementary observations in respect of Parts A and B, appertaining to U.S.A. customers, have already been published by the Bell Telephone Laboratories.[4]

The problem of defining conditions under which satellite circuits should be used is being studied by the C.C.I.T.T. in the light of these results and similar results from observations conducted by other telephone administrations. A draft recommendation was prepared by C.C.I.T.T. Study Group XII at its meeting in Geneva during May 1966, and this will be submitted for approval by the Plenary Assembly in 1968.

FURTHER WORK

This article details the more important results obtained from the tests. The large amount of data collected, however, has not yet been fully analysed, and it is expected that several interesting features will be revealed.

ACKNOWLEDGEMENTS

Acknowledgements are due to those members of the staff of the Post Office Research Station, in particular Mr. R. B. Archbold, who directed the investigation, to the members of External Telecommunications Executive, the Main Lines Development and Maintenance Branch, Engineering Department, and the London Telecommunications Region who were largely responsible for collecting the data, and also to the American Telephone and Telegraph Company, the Bell Telephone Laboratories, the Trans-Canada Telephone System, the Canadian Overseas Telecommunication Corporation and the New Zealand Post Office for their collaboration.

*Compatibility, as applied to echo suppressors, may be defined as follows: Given (*a*) that a particular type of echo suppressor (say Type A) has been designed so that satisfactory performance is achieved when any practical single-link or multi-link connexion is equipped throughout with one or more pairs of half echo suppressors of identical type and (*b*) that another particular type of echo suppressor (say Type B) has likewise been designed, then Type B is said to be compatible with Type A if it is possible to replace any one (or more) of the half echo suppressors at any point in the connexion by that (or those) of the other type without appreciably degrading the performance of the connexion.

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Book Review

"Transistor Bias Tables." E. Wolfendale, B.Sc.(Eng.), M.I.E.E. Iliffe Books, Ltd. 71 pp. 3 ill. 21s.

Here is a very useful book for circuit designers and staff in electronic laboratories who may be concerned with the design of transistor amplifiers. A conventional transistor amplifier stage, with common-emitter configuration, uses two resistors for the potentiometer bias chain on the base input and a third resistor in the emitter. The valves of these three resistors can be read directly from the tables given, for various values of collector voltages, collector current, transistor gain and leakage currents. The collector voltages covered by the tables are 3, 6, 9, 12 and 24 volts, collector currents in 11 steps from 0·1 mA to 10 amps and gains from 20 to 200. The tables can also be used to give a clear picture of the effect of changes in various parameters. This book is for germanium transistors only. A second volume for silicon transistors will be published in the near future.

W.T.L.

An Automatic Error-Correcting Radio-Telegraph Multiplex System

D. A. CHESTERMAN†

U.D.C. 621.394.147.3:621.394.44:621.371

The Van Duuren automatic error-correcting (ARQ) system was introduced by the Post Office on a London–New York radio-telegraph circuit in April 1954. The system was designed to protect long-distance radio-telegraph circuits from errors due to variations in radio-propagation conditions. This article describes the operation of this type of ARQ system, with particular reference to modern transistor-type equipments.

INTRODUCTION

THE principles of automatic error-correction (ARQ) have already been described elsewhere in this Journal[1, 2] with references to improvements to the system.[3] The basic principle of current equipment was produced in about 1950 by Dr. Van Duuren of the Netherlands Post and Telegraph Department, and was put into commercial use in 1953. Whereas the first ARQ equipments were electromechanical, modern equipments are transistor type, and there have been intermediate stages using hot-cathode and cold-cathode valves.

All radio-telex and many international leased and public circuits originating in the United Kingdom are protected, i.e. the radio or cable links operate via ARQ equipment located in the overseas telegraph terminals in Electra House or Fleet Building in London. The annual growth of overseas telex traffic is about 20 per cent, and the demand for ARQ equipment is further stimulated by the necessity to replace obsolescent electromechanical equipment in the near future. It is estimated that there are at least 1,000 equipments in service throughout the world, and, of these, 175 are now installed in or on order for London to give a total of 554 full-character-rate channels.

GENERAL PRINCIPLES OF ARQ WORKING

It is useful to refer again to some of the principles involved in ARQ working, before considering the system in detail. For simplicity, a leased, or private, point-to-point circuit is considered: the customer's equipment is assumed to comprise a teleprinter to receive traffic, a means of punching paper tape, e.g. a keyboard perforator, and a pulse-controlled automatic transmitter to send the traffic prepared on the perforator. To transmit a message the punched tape is placed under the head of the automatic transmitter, and traffic is sent forward, character by character, as controlled by release pulses from the ARQ terminal. Should the path between the ARQ terminals fail in either direction then these release pulses stop, thus arresting the progress of the tape until the path is restored; the transmission of release pulses from the ARQ terminal to the customer then recommences.

The system requires two terminals, one termed the master and the other the slave. Each terminal can multiplex together two or four channels by time division, i.e. it can combine them in a predetermined cyclic order for transmission over a common path. By translating each teleprinter character into a 7-unit code having a constant element, or bit, polarity ratio of 3:4, any received signals that do not comply with this criterion are detected as errors. For example, assuming that positive polarity is represented by A and negative by Z, then character N would be translated from AAZZA in 5-unit form to ZAZAZAA. Should this be received as, say, ZAAAZAA then, as this fails to conform to the criterion for acceptable characters of a 3:4 ratio of Z to A polarity signal elements, it is identified as a detectable error.

On the detection of an error the transmission of character-release pulses to the local customer's automatic transmitter is stopped and the receive wire is held permanently to stop polarity. Hence, all traffic to and from the customer and the ARQ terminal ceases. The ARQ terminal sends a demand-for-repetition (RQ) signal over the radio path, followed by the last three characters that were transmitted prior to the receipt of the error. The RQ signal plus the repeated characters are known collectively as a repetition cycle. Upon receipt of this RQ signal at the distant terminal all local traffic is ceased and a repetition cycle is transmitted back to the terminal that originally received the error. The transmission of these repetition cycles continues in both directions until one complete cycle is received correctly at the terminal that received the error; transmission of character-release pulses is then resumed and traffic recommences to and from the local customer. This terminal ceases to transmit repetition cycles, and the distant terminal will resume traffic when the RQ signals cease on the incoming path.

Synchronous Working

In common with other communication systems, the provision of additional telegraph circuits is often restricted by the non-availability of bandwidth. The conventional 50-baud 7½-unit start-stop teleprinter signal consists of one start element, five information elements and one and a half stop elements; hence, one third of the signal is utilized to start and stop the receiving teleprinter and only two thirds contains traffic information. On circuits where bandwidth is restricted, start-stop working is thus very inefficient. By eliminating the machine start and stop elements from the signal it is possible to pass only information between two terminals, providing that this is transmitted and received continuously. The information signals then represent either an idle condition or traffic.

In a start-stop system each transmitted character is timed from the start element; synchronization between transmit and receive machines is maintained by independently-controlled motors. It could thus be said that, with start-stop working, the receiving teleprinter operates synchronously over each character.

For continuous synchronous working it is not possible to rely entirely on governed motors or even on oven-controlled crystal oscillators to maintain synchronism;

†Telegraph and Data Systems Branch, Engineering Department.

drift will occur eventually unless some corrective action is taken at the receiver. In practice, the receiver corrects the speed of the local oscillator, or "clock," to that of the transmitter by a comparison of locally-generated element-rate pulses with the transitions of the incoming signal. By the use of "early" gates and "late" gates and a suitable integrator to prevent jitter, corrections of the local clock are made in such a way as to ensure that the sampling of the incoming signal is always within 1 per cent of the centre point of each element (Fig. 1).

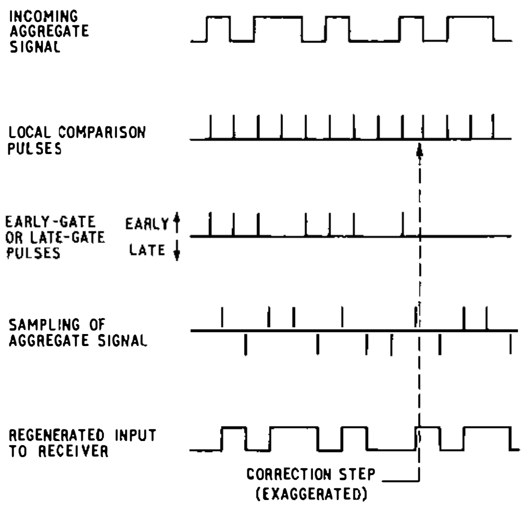


FIG. 1—USE OF EARLY AND LATE GATES ON SYNCHRONIZER

In addition to making better use of available bandwidth, synchronous operation confers the advantage that signals can be accepted with twice the distortion that would be acceptable for start-stop working.

Multiplex Working

Current ARQ equipment can operate as a 2-channel, i.e. diplex, or as a 4-channel system. The information elements are transmitted from each channel in turn on a single, or aggregate, path. Aggregation is performed systematically by a distributor at the transmitter, and a similar distributor at the receiver separates the aggregate into the constituent channels.

The use of the C.C.I.T.T.* 7-unit code will give, for 2-channel working, an aggregate element length of $145\frac{5}{6}/7 \times 2$ ms, i.e. approximately 10·4 ms, and the aggregate modulation rate will be $2 \times 7 \times 1000 \times 6/[(145 \times 6) + 5]$ bauds, i.e. 96 bauds.

The character length is $145\frac{5}{6}$ ms, and the character rate is $411\frac{3}{7}$ characters/minute, both being C.C.I.T.T. Recommendations. This character rate is slightly faster than the teleprinter speed of 400 characters/minute; hence, on telex working, where traffic is originated by an uncontrolled or random transmitter, there is an adequate margin of speed to prevent the originating machine from overtaking the synchronous equipment.

In any multiplex system it is essential to ensure that channels cannot become crossed, i.e. the traffic on channel A must not be received on channel B or vice versa. In a frequency-division system, such as a multi-circuit voice-frequency telegraph system, this is prevented by band-pass filters on each channel. With time division it is necessary to mark one channel in such a way that it can be distinguished from another; a simple way of accomplishing this is to invert the polarity of its signals at each terminal.

In ARQ working the channel inversions are as follows.

Two-Channel Working	*Four-Channel Working*
Channel A: Erect	Channel A: Erect
Channel B: Inverted	Channel B: Inverted
	Channel C: Inverted
	Channel D: Erect

Even with this precaution it is possible to cross channels in 2-channel working if the aggregate is inadvertently inverted. This is safeguarded by the marked character cycle in which, in addition to the normal channel-inversion pattern, one character in every repetition-cycle period, i.e. one per four or eight characters, on each channel is inverted.

Multiplexing on ARQ equipment is achieved by character interleaving for 2-channel working and by a combination of character and element interleaving for 4-channel operation. Hence, the aggregate signals will be of the following forms where, for example, $A1_7$ represents element 7 of character 1 on channel A, and $C2_1$ represents element 1 of character 2 on channel C.

Two-Channel Working: $A1_1$, $A1_2$....$A1_7$, $B1_1$, $B1_2$....$B1_7$, $A2_1$, et seq.

Four-Channel Working: $A1_1$, $C1_1$, $A1_2$, $C1_2$....$A1_7$, $C1_7$, $B1_1$, $D1_1$....$B1_7$, $D1_7$, $A2_1$, $C2_1$, et seq.

Internal Clock

To keep an ARQ receiver in synchronism with the distant ARQ transmitter it is necessary to correct the local timing automatically to keep it in step with the transitions of the incoming signal. Should the transmission path fail, e.g. due to a radio fade or a land-line failure, then the receiver cannot be corrected and it becomes free-running. It is very desirable that, on the restoration of the transmission path, the receiver should not have drifted so far as to be out of phase with the transmitter, and providing that the drift is within one half of an element then phase will not be lost. By ensuring that the local oscillators at both terminals are accurate and stable to one part in a million, breaks of up to 40 minutes can be tolerated on a 2-channel system, or up to 20 minutes on a 4-channel system. Such a stability is now recommended by the C.C.I.T.T., and a modern crystal oscillator enclosed in a thermostatically-controlled oven can readily achieve it. The crystal frequency specified by the British Post Office is 9·6 kHz, this being the lowest frequency to ensure that 1 per cent corrective steps can be taken on 4-channel working, i.e. with step timing changes of 52 μs.

It is possible for random signals, due to noise, to drive a receiver out of a true synchronous position and hence cause it to lose phase. Such noise would result in the channels cycling due to the receipt of errors, so as a precaution, when all channels on a system are cycling to errors, correction is inhibited automatically.

Master–Slave Working

In an ARQ system one terminal, termed the master, is used to control the timing of both the master and the distant slave terminals. The timing of the transmitter at the master is controlled by its own clock, whereas at the slave both receiver and transmitter are controlled by the

*C.C.I.T.T.—International Telegraph and Telephone Consultative Committee.

slave clock as corrected by the incoming transitions. The master receiver also is controlled by its own clock as corrected by the incoming transitions; hence the clock at the master controls the whole system (Fig. 2). It might

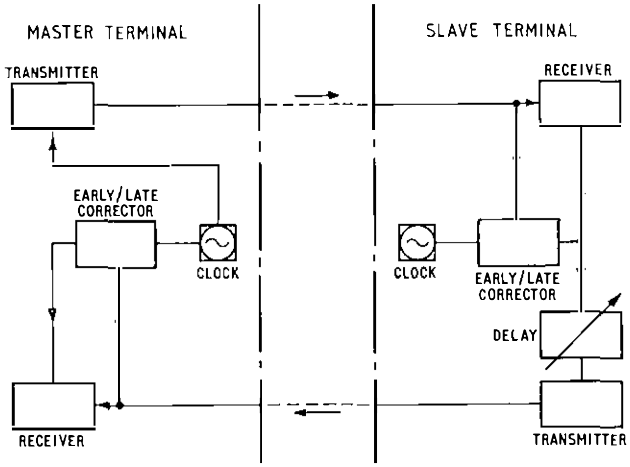


FIG. 2—MASTER-SLAVE WORKING

be thought that once the system is set up further corrections at each receiver would be unnecessary, but due to the variations in radio-propagation time such corrections must continue to be made to ensure correct synchronization at all times.

TRANSMITTER

The ARQ transmitter calls in traffic, character by character, from each channel in turn, encodes all traffic and idle conditions, and transmits a multiplexed, or aggregate, signal towards the distant terminal. A 3-character or 7-character store is provided to permit repetition of traffic when so required by the receiver.

Control of Customers' Equipment

In general, a synchronous system cannot accept random-arrival traffic, e.g. traffic transmitted by a teleprinter as controlled by its keyboard. This is because characters are sent forward from the ARQ equipment to the radio link in predetermined time slots, and it is improbable that these would coincide with a random input. Therefore, the ARQ terminal demands traffic from the local incoming channel by sending out character-release, or demand, pulses. As already described, for protected leased circuits, a pulse-controlled automatic transmitter is used to generate 7-unit start-stop signals from pre-punched tape. In addition to timing the character input to the ARQ, it will be seen later that the character-release pulses have an important function during the error-correction procedure. It is essential that the cycle time of the remotely-controlled local transmitter should be shorter than that of the ARQ equipment, and, to ensure this, the start-stop signal from the pulsed automatic transmitter is 7-unit, whereas the ARQ character rate is equivalent to a 7·28-unit signal at 50 bauds.

International telex traffic originates from standard telex installations which do not include pulse-controlled automatic transmitters, consequently special equipment is required at the ARQ terminal. This aspect will be dealt with in a later paragraph.

Start-Stop-Signal to Coincident-Signal Converter

The local-channel input to an ARQ equipment is coincident, or parallel, 5-wire. To convert the incoming start-stop signal to a coincident 5-wire condition necessitates the use of a converter which staticizes each character and presents a 5-wire output to the ARQ equipment. These converters are used on leased and public circuits, and are accommodated on an auxiliary rack adjacent to the ARQ equipment.

Traffic and Supervisory Conditions

As already explained, a synchronous system must always be passing signals between terminals. A sixth wire from the start-stop converter indicates to the ARQ transmitter whether there is traffic to be sent; if there is no traffic present then the condition on the sixth wire changes to indicate that an idle signal is to be transmitted. A seventh wire is required to signal which of the two idle conditions, idle alpha or idle beta, is to be transmitted (Fig. 3). For telex traffic, idle alpha corresponds to

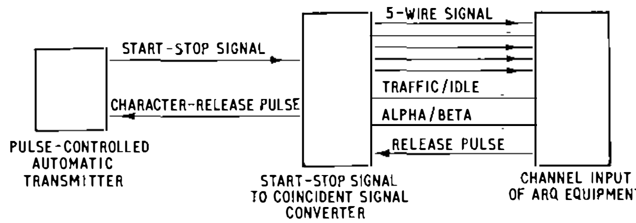
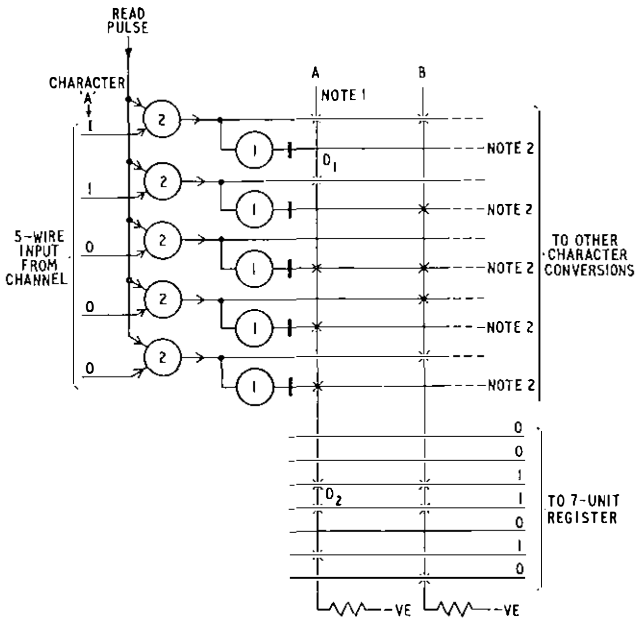


FIG. 3—BLOCK SCHEMATIC DIAGRAM OF CHANNEL INPUT

continuous start polarity on the channel input, and this indicates a clearing, or free, condition. Idle beta corresponds to continuous stop polarity, indicating a calling, or held but idle, condition on the telex channel. Leased traffic generally requires only one idle condition, and this is usually idle beta.

A traffic character is now considered to have been staticized in the start-stop converter and a traffic condition signalled to the ARQ equipment. Before transmission by radio the character has to be converted to the 7-unit error-detecting code. The 5-wire coincident input is a convenient form for such conversion, which can be effected in a number of ways. One method employs ferrite cores so arranged in a pattern that when a read pulse is applied to encode a character, only three out of seven of the output wires will be activated, according to the particular code required. Another system uses a diode matrix, and a typical translation is shown in Fig. 4. Each combination of the 5-unit code is connected to one of 32 vertical wires by diodes D1. When one of these wires is biassed by its input combination then a corresponding 7-unit coincident signal appears on the output wires via the diodes D2. In the example shown, character A is converted from ZZAAA to AAZZAZA. The supervisory signals alpha and beta, as well as the RQ signal, are outside the 32 combinations of the keyboard alphabet, and additional input wires to the matrix are necessary to produce the 7-unit codes corresponding to these signals. The output of the coder will set up the code on an output register, which holds the character until it is transmitted sequentially by the transmit distributor.



Notes: 1. Connexion at this point is as indicated thus:

2. Signal on this lead is always of opposite polarity to that on lead shown above.
3. 0 = positive, or A, polarity
1 = negative, or Z, polarity.

FIG. 4—DIODE MATRIX FOR CODE CONVERSION

Transmit Distributor and Aggregate Keyer

The speed of operation of the code converter is such that it can be used for both channels of a diplex; hence, the output register presents information from channels A and B alternately. This register is read in elemental order by a distributor that steps at the aggregate element-rate, i.e. approximately every 10·4 ms, for 2-channel working. The channel and marked character cycle inversions are applied by the aggregate keyer, which presents a polar signal to line. Where the multi-circuit voice-frequency telegraph equipment linking the ARQ equipment to the radio stations is situated adjacent to the ARQ terminal, the signalling voltage may be ±6 volts, otherwise it is ±80 volts. With the introduction of electronic relays the high maintenance liability of electro-mechanical 80-volt polar relays is eliminated.

Repetition Store

The receipt of an RQ signal or a detectable error by the receiver will cause the transmitter to send a repetition cycle, i.e. an RQ signal followed by the repetition of a predetermined number of characters that were transmitted immediately prior to the receipt of the RQ signal or detectable error. The number of repeated characters is usually three, but for circuits with an abnormally long propagation time the repetition cycle is increased from a total of four characters to a cycle of eight, i.e. RQ+seven characters repeated from the store. Hence, it is necessary at all times to have this information stored in readiness for re-transmission. The store is generally at the 7-unit stage, i.e. after code conversion, and consists of a 3-position or 7-position, 7-line shift-register, each element being stored on a 2-state logic device. This device is generally a transistor-type trigger, but a ferrite core is used in some equipment.

When a repetition is required the store output, which is disconnected in normal traffic, is connected to the aggregate keyer in place of the output from the code converter, and the stored information also circulates back into the store. An RQ signal generator is called in to transmit an RQ signal prior to every repetition from the store; the RQ signal is not stored.

RECEIVER

The function of the receiver is to convert the aggregate signal into start-stop traffic appropriate to the individual channels. It must also detect errors and RQ signals, and initiate repetition cycles as required.

Receive Distributor

The aggregate signal is re-inverted under the control of the channel and marked character cycle inverters, and then staticized as a 7-wire presentation on a register via the receive distributor. On receipt of the seventh element the signal is offered to the code converter.

Code Converter

The 7-wire signal is decoded by a matrix similar to the 5-wire-to-7-wire converter, and if the signal is acceptable it presents a 5-wire output to the A-channel register. The code converter is then available to accept a further 7-wire input from the receive distributor for presentation to the B-channel register. Receipt of an RQ signal, or an error, will initiate a repetition cycle, as already described in the paragraph headed Repetition Store. While a channel is cycling, whether due to the receipt of errors or to the receipt of RQ signals, the character-release pulses are not sent to that channel end. Hence no traffic is called in, and it follows that, when traffic is resumed, no traffic will have been lost.

Error Detection

There are two principal methods of detecting unacceptable, i.e. non 3:4 ratio, combinations. One is to use an A, or a Z, element counter and to check that each

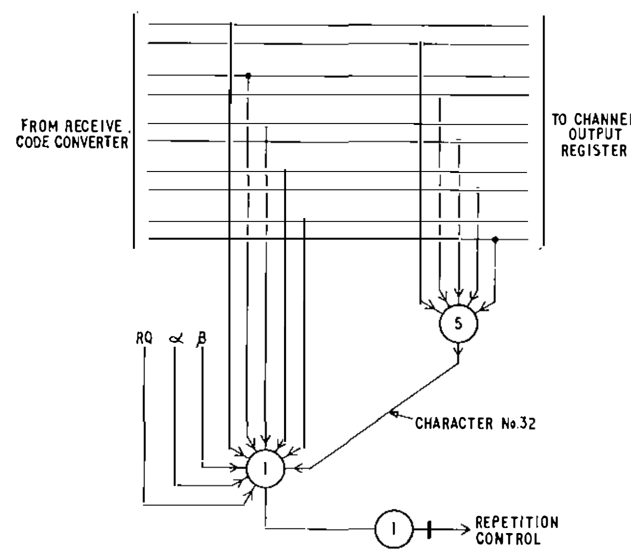


FIG. 5 ERROR DETECTION

7-wire presentation conforms to the 3:4 criterion. Another method is to connect together via an OR gate the 5-wire outputs of the code converter, the RQ and the idle-signal outputs, and the output for character 32 (all-start combination) in such a way that the absence of an output from the gate indicates that the 7-wire signal is a combination other than one of the acceptable 35 and is, therefore, an error (Fig. 5).

Channel Output

Acceptable characters are presented to each channel register in turn and transmitted to the local line as 7·28-unit, 50-baud, start-stop signals by a start-stop distributor. During periods of no traffic the channel output wire is held to constant polarity, according to the prevailing idle signal, alpha or beta.

Automatic Phasing

The corrective action of the terminal receiver ensures that every received element is sampled at the optimum, i.e. mid, point. However, a receiving distributor could be out of step with the transmitting distributor. For example, at a given instant channel A, character 2, element 6 at the receiver might be offered channel B, character 4, element 1, by the aggregate distributor and, due to the corrective action of the receiver, this situation would persist indefinitely, causing all channels to cycle to the receipt of errors. These errors can be used as a criterion to indicate an out-of-phase condition. In the equipment described, whenever all channels cycle continuously to the receipt of errors for a period of about 5 minutes then the receiver is considered to be out of phase. Automatic phasing is then switched on and the receive distributor is retarded by one element for every error received until acceptable repetition cycles are detected on all channels; the receiver is then considered to be in phase and the automatic phasing is automatically switched off. Phasing is an important feature in ARQ working, and the following facilities can be selected by a switch:

(*i*) phasing off,
(*ii*) manual phasing in element steps,
(*iii*) automatic phasing, manually initiated, and
(*iv*) automatic phasing, automatically initiated.

Facility (*iv*) is generally used for normal traffic operations.

TELEX WORKING

About 45 per cent of all ARQ circuits are utilized for telex and this percentage is increasing. The subject of international automatic telex switching[4] is outside the scope of this article, but certain aspects are now considered insofar as they concern the ARQ equipment.

Buffer Storage

The telex customer's machine is a random transmission device, as it is not controlled by any external pulses. To effect such control would involve prohibitive complexity of the national telex network, and it is therefore necessary to provide a buffer between the random-arrival traffic from the customer and the ARQ terminal. This buffer has a further function: to provide storage during periods of cycling. The original type of store was a fully automatic reperforator transmitter distributor (FRXD) which employed perforated paper tape for storage. The FRXD is electromechanical and, with the necessity to change the tape every 100,000 characters, considerable servicing attention is required.

A later device in use by the British Post Office is electronic, using a magnetic drum[5] as a storage medium, with a minimum capacity of 4,000 characters per telex circuit. Whenever a character is read out to the ARQ equipment, that "position" in the store is available for reading-in. Hence, the capacity of 4,000 represents a back-log of 10 minutes' traffic arising from periods of cycling, and, in practice, it is not expected that this capacity will be taken up except under abnormal radio conditions or in the event of an equipment breakdown. Another type of equipment with similar facilities and employing a magnetic-tape loop with a small electronic bridging store has now been introduced into service.

These storage devices all perform four principal functions.

(*i*) To act as a buffer between random or uncontrolled arrival traffic and the controlled demands for traffic by the ARQ terminal.

(*ii*) To store traffic during periods of cycling on the ARQ system.

(*iii*) To present traffic to the ARQ in 5-wire staticized form.

(*iv*) To signal to the ARQ terminal via the telex panel whether traffic is present in the store or not.

Telex Panel

The telex line, and the ARQ and buffer-store equipments are interconnected and controlled by the telex panel (Fig. 6), which performs the following principal functions.

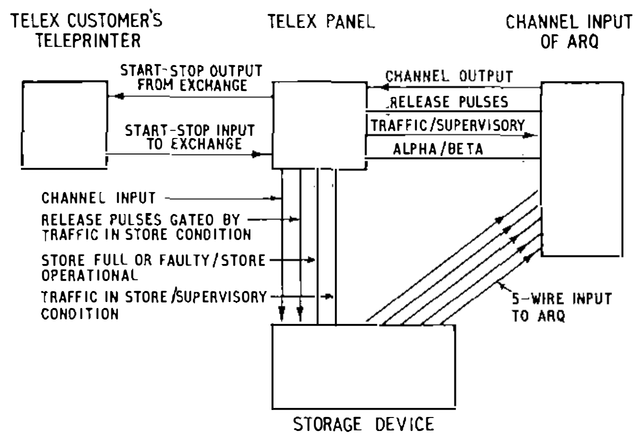


FIG. 6—INTERCONNEXIONS OF TELEX PANEL, STORAGE DEVICE AND ARQ INPUT

(*a*) It differentiates between traffic and idle conditions on the local incoming wire.

(*b*) It indicates "traffic/no traffic in store" to the ARQ equipment.

(*c*) It repeats the ARQ character-release pulses to the store, and controls the first and last characters in a block of traffic.

(*d*) It repeats the character-release pulses to the telex exchange for metering pulses.

(*e*) It indicates "tape low" (on FRXD only) to the telex exchange to prevent a subsequent call maturing.

(*f*) It initiates a forward clear when the "store out of order" condition is received from storage.

(*g*) It clears the store on receipt of a clear from the radio terminal.

(*h*) It presents and accepts the appropriate signalling levels at the telex exchange, storage, monitor and ARQ interfaces.

(*i*) It provides for the transmission and detection of a predetermined count of successive alpha or beta periods as required for signalling purposes by C.C.I.T.T. Recommendation U20. The simplified supervisory signalling requirements are as follows:

	Transmit	*Detect at Receiver*
Calling	4 betas	2 betas
Clearing	7–11 alphas	2 alphas

All the above signalling groups must be consecutive.

OTHER FACILITIES

Sub-Division

A useful facility of ARQ, resulting from the synchronous mode of operation, is that of sub-division, whereby a number of customers share a full-character-rate channel. Such circuits are attractive for lessors who may have, say, only 4 hours traffic to clear every 24 hours, but require to have a circuit available on a 24-hour basis. These subdivided channels are usually referred to as part-character-rate channels. The division rate must bear a simple relation to the duration of the repetition cycle, hence ¼ is the basis for sub-division. A quarter-character-rate customer will clear one character every 580 ms approximately, the three "blank" character periods being filled by traffic from other part-character-rate customers. During periods of no traffic the output of that sub-channel is held to stop polarity. The possible combinations of subdivided working are $4 \times \frac{1}{4}$, $2 \times \frac{1}{2}$, $2 \times \frac{1}{4} + 1 \times \frac{1}{2}$ and $1 \times \frac{1}{4} + 1 \times \frac{3}{4}$, this latter being used only exceptionally, e.g. where a public circuit is reduced to ¾ rate to accommodate a requirement for ¼-rate leased circuit.

In the same way that it is necessary to ensure against main, or full-character-rate, channels being inadvertently crossed in traffic, so it is equally important to protect sub-channels. This is readily achieved by inverting one character in four; the sub-channels are numbered 1–4, and the first sub-channel of any main channel is inverted. In early subdividers this inversion, or marking, pattern was derived from a distributor on the subdivider itself, independent of the main equipment. An inversion pulse was transmitted to the aggregate keyer every fourth character per subdivided main channel. If, contrary to normal practice, two channels of a multiplex were subdivided, a careful and laborious procedure had to be followed at both receivers in setting up because there was no fixed relationship between the main-channel inversion patterns required for sub-division. A modern subdivider is a relatively simple switching and gating device accommodated on the main equipment, the necessary distribution pulses being derived from the marked-cycle distributor, or equivalent, within the ARQ equipment itself.

Marked-Character Cycle

By the use of a circuit timing diagram, it can be shown readily that, during rephasing, two terminals can drift out of relative system-phase relationship, i.e. an A1 character could be received otherwise, as, say, A3. This would result in the duplication of two characters at one terminal and the omission of two characters at the other terminal. One, two or three characters can be duplicated or omitted at each terminal, according to the degree and direction of drift: there is, in fact, only a one-in-four chance of finding correct system phase after a rephasing process. To overcome this defect the marked-character cycle has been introduced and is now a C.C.I.T.T. recommendation.

The marked-character cycle requires the inversion of one character in every repetition-cycle period per main channel, regardless of the application of sub-division. A predetermined and fixed relationship between these channel-marking patterns ensures correct system phase under all circumstances. The marked or inverted character is the first of every four (for a 4-character repetition cycle) and the following shows the actual marking and character-interleaving patterns (the bar indicating an inverted character).

Two-channel working:

$$\overline{A}_1\ B_4\ A_2\ \overline{B}_1\ A_3\ B_2\ A_4\ B_3\ \overline{A}_1\ B_4, \text{ et seq.}$$

Four-channel working:

$$\overline{A}_1\ B_4\ A_2\ \overline{B}_1\ A_3\ B_2\ A_4\ B_3\ \overline{A}_1\ B_4$$
$$\overline{C}_1\ \overline{D}_1\ C_2\ D_2\ C_3\ D_3\ C_4\ D_4\ \overline{C}_1, \text{ et seq.}$$

Channels A and C, and B and D are element-interleaved in this pattern.

The pattern shown above at once ensures correct cycle phase and provides the marking necessary for sub-division. Hence, for sub-division, no separate marking is required; it is necessary only to connect the traffic and character-release pulses to the appropriate circuits via the subdivider.

Error Indication

On circuits using ARQ equipment but which have no return path, a system called E.I. (Error Indication) is used. As the name implies, each received error is printed on a modified teleprinter receiver as a "crab" symbol. The RQ combination is not used, and automatic-phasing is not possible as the in-phase criteria cannot be met.

Phasing is achieved manually, and synchronization maintains phase except during receipt of errors. This system has little application, and no such circuits work to or from London at present.

PHYSICAL DESIGN

The early electromechanical ARQ equipments (Fig. 7) are still in service at Electra House, London, and a modern transistor counterpart is shown in Fig. 8. With this latter equipment there is a fourfold saving in space, and in-service faults are reduced by about two orders.

In the transistor equipment the logic elements are mounted on a printed-wiring "father" board, which is accommodated in a "book" that slides into the cabinet and effects connexion with other books by a gold-plated printed-wiring edge-connector or multi-pin plug. All current ARQ equipments are mains operated, and are generally cooled by an extractor fan.

An important feature of the cabinet is the control panel (Fig. 9), where a number of channel and common controls are conveniently situated. To reduce cabling and floor-space requirements, interconnexions between main and auxiliary ARQ cabinets or racks are effected on a patching-jack field which enables channels and auxiliary units to be changed rapidly whenever required.

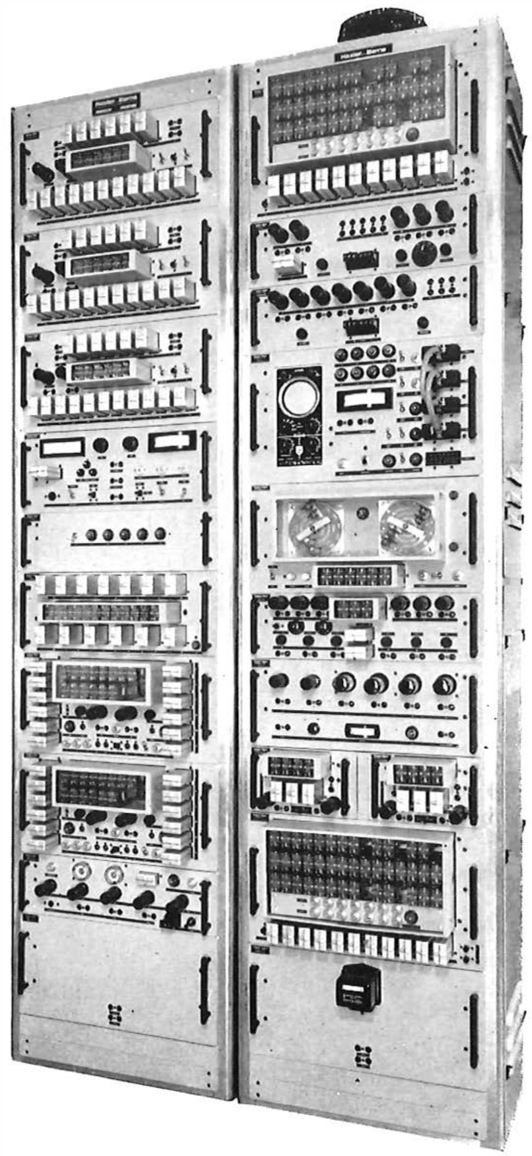


FIG. 7—ELECTROMECHANICAL ARQ EQUIPMENT

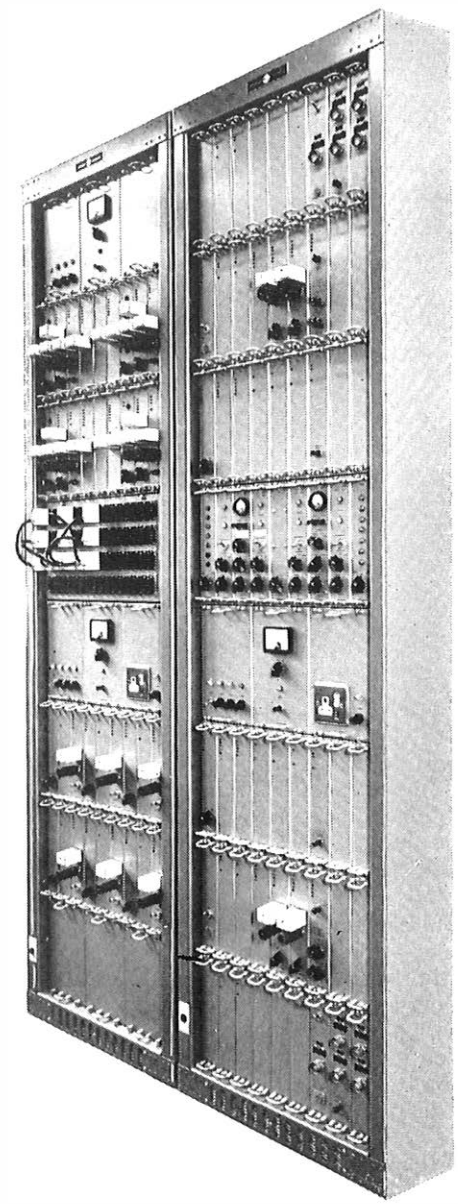


FIG. 8—TRANSISTOR-TYPE ARQ EQUIPMENT

POSSIBLE DEVELOPMENTS

The original system has been made more efficient in a number of respects; there now appears to be only a limited scope for further improvements, but three are considered.

Speed of Automatic Phasing

The speed of automatic phasing is governed by a number of factors, but those principally concerned are as follows.

(*a*) Whether the mode of working is 2-channel or 4-channel.

(*b*) Whether marked-character cycle (or sub-division) is in operation.

(*c*) The system for determining when the in-phase criteria are met.

In current systems, a one-element phase step is taken for every error received (with certain qualifications), and it may be necessary for phase-stepping to continue for the duration of some 40 repetition cycles before correct phase is found. By using a large shift-register and elaborate gating it is possible to re-phase within one repetition cycle, with a consequent increase in available traffic time, albeit very small.

Reduction in Undetected-Error Rate

The undetected-error rate could be further reduced by introducing a single-character store on each receive channel, every received character being held in this store until the following character has been received and checked as acceptable. If this second character is a detectable error then the first character is rejected. The logic of this arrangement is that, if line-propagation conditions are such as to cause detectable errors, then it is probable that adjacent characters may be undetectable errors. An undetectable error is a received character mutilated in such a way that it has lost its original identity but still

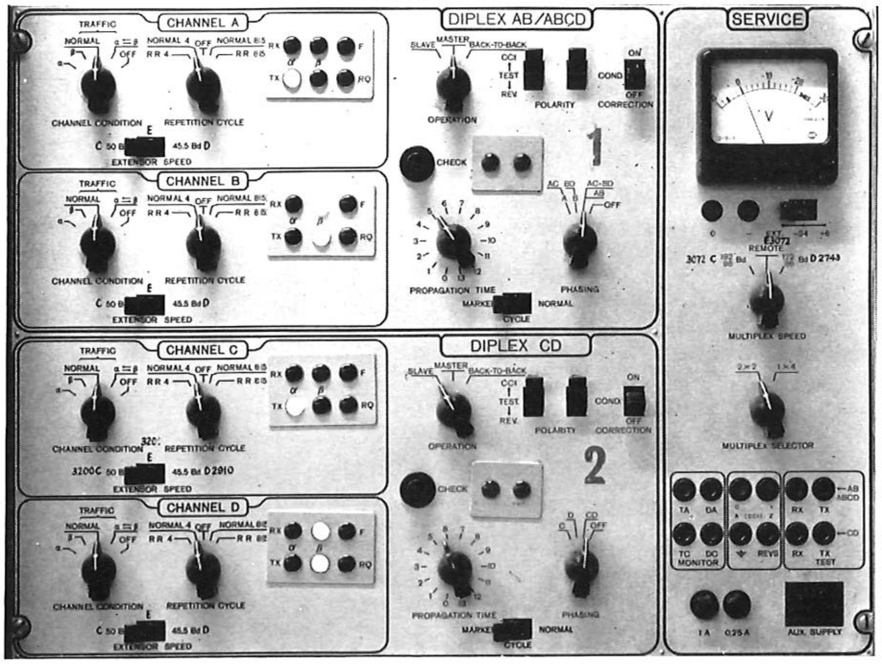


FIG. 9—CONTROL PANEL

conforms to the 3:4 criterion; this could be caused by the transposition of two unlike elements.

Both of the foregoing improvements would require considerable modification of the equipment and it is improbable that they would justify the financial outlay.

Computer ARQ

The requirements of character storage for repetition and for telex—predictable programs and comparatively low operating speeds—suggest the use of a computer in place of perhaps 12 conventional ARQ equipments together with all their associated auxiliaries. This should result in a considerable saving in capital cost, and a reduction in floor space and in power consumption. A further advantage is that, should any additional facility be required or should an existing facility require to be modified, e.g. if the telex clearing signal was changed from two alphas to three, then it would be necessary to change only the computer program for that particular feature.

CONCLUSION

For radio and long transoceanic cable circuits the introduction of multiplex ARQ equipment can double the number of full-character-rate channels, provide sub-divided channels and give a valuable improvement in the detectable error-rate. The number of equipments in service in the British Post Office has expanded rapidly since their introduction in 1954, and there is no indication that this trend will diminish for a number of years.

ACKNOWLEDGEMENT

Acknowledgement is made to Messrs. Hasler of Berne, Switzerland, for permission to use the photograph in Fig. 7.

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Book Review

"Operational Methods in Nonlinear Systems." Louis A. Pipes. Constable and Co., Ltd. 99 pp. 640 ill. 12s.

This is a valuable little book. The field covered is an important one in view of its many technical applications but is not as understood as it should be, possibly because the existing literature is somewhat scattered.

The preface describes the object of the book as being to describe the various methods which are available for the solution of non-linear differential equations of the non-autonomous type; that is, equations in which the independent variable appears explicitly. It is precisely this type of equation which is most scantily dealt with in existing literature and which is of most interest to engineers.

The presentation adopted is suitable to an engineer or physicist in that the various methods described are amply illustrated by examples of practical physical problems. The mathematics used is business-like and clear, and does not suffer from the looseness which so often characterises mathematical books written for non-mathematicians. The operational methods used are not, in general, essential to the developments but lead to considerable simplification both in the presentation and in the algebraic manipulations required.

The technical problems dealt with include the analysis of a number of non-linear circuits and a discussion of the phenomenon of sub-harmonic resonance.

T.B.M.N.

Transatlantic Telephone Cable TAT-1 Plus Ten Years

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U.D.C. 621.315.28 (261)

The first 10 years of service of the first transatlantic telephone cable, TAT-1, are reviewed both as regards the performance of the TAT-1 system itself and the rapid growth of the oceanic telephone-cable network. The changes in permissible circuit parameters, and in maintenance arrangements, necessitated by very long inter-continental telephone circuits, are also described.

INTRODUCTION

THE first transatlantic telephone cable[1] (TAT-1) opened for service on 25 September 1956. This article is a review of the first 10 years: how TAT-1 itself has performed, and how that first system has led to many more submarine telephone-cable systems to meet the ever-increasing demand for world-wide communications. The large increase in traffic between Britain and U.S.A. and Canada is illustrated by the figures given in the following table.

Weekly Average Calls Before TAT-1 and 10 Years Later

	Before Opening of Cable		10 Years Later	
	U.S.A.	Canada	U.S.A.	Canada
Outgoing full-rate calls	720	120	7,500	1,320
Outgoing cheap-rate calls	550	110	3,300	930
Total outgoing	1,270	230	10,800	2,250
Total incoming	1,050	300	9,850	3,920
Total calls	2,320	530	20,650	6,170
Average duration in paid minutes of outgoing calls	6·75	6·25	8·9	7·7

The total telephone-circuit capacity across the North Atlantic provided by submarine cables is now 281 circuits in cables landing in the United Kingdom and 176 circuits in cables from France. A further 108 circuits are obtained using T.A.S.I.[2] equipment.

SYSTEM PERFORMANCE

In engineering the TAT-1 system, reliability of performance was of paramount importance because the repair of any faults in the system would be very expensive. Hence, the engineering and design technique used were of proven integrity,[3] and meticulous care was taken during the manufacturing and inspection stages to provide extremely reliable equipment. How successful the designers of the system have been in their objectives can be gauged from the history of the first 10 years of the TAT-1 system.

It will be recalled that the TAT-1 system consists of two cable systems. The system between Oban (Scotland) and Clarenville (Newfoundland) is a two-cable system designed by the Bell System. Each cable is 1,940 nautical miles long, with 51 repeaters inserted at approximately 37-nautical-mile intervals. Each repeater contains 66 components, including three thermionic valves. The system between Newfoundland and Sydney Mines (Nova Scotia) is a one-cable system designed by the British Post Office. The cable is 326 nautical miles long, with 16 repeaters inserted at approximately 20-nautical-mile intervals. Each repeater contains approximately 300 components, including six thermionic valves. Thus, the total amount of submerged plant consists of 4,200 nautical miles of cables and 118 repeaters containing approximately 11,500 components. The fault history during the past 10 years for this amount of equipment amounts to 19 cable faults, all due to trawler activity, and one repeater flash-over. The repeater flash-over occurred during the fourth year, when the protective gas-discharge tube of the first repeater at the Clarenville end of the cable to Oban flashed. The reason for the protective gas-discharge tube flashing is not known, but it can be assumed to have been due to a possible voltage wave-front travelling along the cable. Power was removed from the system to extinguish the discharge tube, and the system re-powered. The trouble has not recurred.

Cable Performance

The out-of-service time has resulted almost entirely from cable faults. Of the 19 cable faults reported above, 16 have occurred off Newfoundland and three off Scotland. The total out-of-service time due to faults or incidents in the submerged plant during 10 years of operation is approximately 74 days: ignoring trawler damage, the out-of-service time is reduced to 4½ hours. It can thus be truly said that, so far, the objectives of the designers have been fulfilled. Credit is also due to the hundreds of people who were engaged in the manufacture of the cable and repeaters to the very exacting standards necessary to achieve such high reliability.

Trawler damage has been the main cause of faults in other telephone-cable systems. Considering all the telephone cables that have been laid between Europe and North America there has been a total of 56 cable faults in the North Atlantic, 81 per cent of which have been in the vicinity of Newfoundland, where there are, of course, good fishing grounds. Because of the high fault-rate in this area, it is now the practice to maintain a cable ship on patrol. The ship keeps watch on the cable routes and attempts to keep trawlers away, thus preventing damage. Should a fault occur, however, the ship is equipped and ready to deal with any fault on any of the systems. The patrol is shared by cable ships of the United Kingdom, U.S.A., Canada and France.

One of the serious technical difficulties which emerged in the TAT-1 system was the unexpected change in cable attenuation which occurred during laying, over and above that expected due to temperature and pressure changes. This effect continued to operate for several years, thus affecting the electrical alignment of the system. On the Clarenville–Sydney Mines section, this aging effect has resulted in a decrease of 4 dB in the overall loss, and in the Clarenville–Oban section a decrease of 15 dB has occurred. These changes have had to be compensated for at the terminal stations and have resulted in an increase in noise in some channels. Where the channel

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noise has increased beyond the objective of −46 dBmOp,* compandors have been inserted. At present three channels are equipped with compandors in the Oban–Sydney Mines direction and eight channels in the other direction.

The decrease in cable attenuation with time has been termed the "aging effect." It is believed that the effect is due to the presence of the short-lay copper binding tape lapped over the return-conductor tapes.[4]

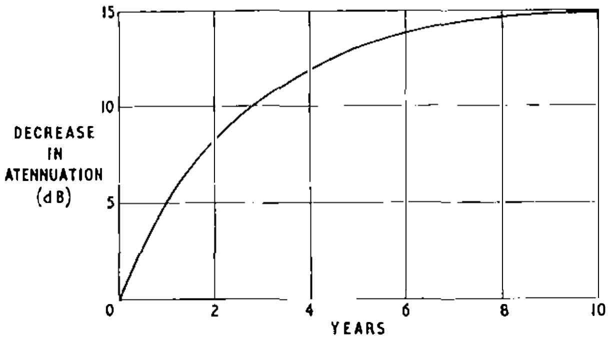

FIG. 1—AGING OF CLARENVILLE–OBAN CABLE

Fig. 1 shows the change of attenuation due to aging effect with time. It can be seen that the change has now become almost negligible. New cable designs, in particular the British Post Office 1 in. Lightweight cable,[5] have almost completely eliminated changes of cable attenuation due to aging.

Power-Feeding Equipment

The design of the power-feeding equipment has proved satisfactory and shown itself capable of maintaining constant current to line during magnetic storms, when the difference in earth potentials between the two terminals can reach high values. On the Clarenville–Sydney Mines section, 1,400 volts has been attributed to magnetic-storm effects.

Circuit Performance

The TAT-1 system was designed to provide three 60–108 kHz groups, and initially was equipped with 4 kHz-spaced channel equipment. Later, 3 kHz-spaced channel equipment[6] was provided at Oban and Sydney Mines, giving a total of 48 channels in each direction of transmission. Three additional channels were obtained outside the planned transmission band, so the system now provides 51 channels in each direction of transmission. Normal 4 kHz-spaced channels are used between London and Oban, and from Sydney Mines to New York and Montreal.

Time assignment speech interpolation (T.A.S.I.) equipment[2] has been provided at London and New York, making it possible to increase the capacity of the system by a further 36 circuits.

At the time of the early discussions on the design of the system, the only international noise standard was the C.C.I.T.T.† recommendation which, based on a hypothetical circuit 2,500 km long, allowed 7,500 pW (i.e. 3 pW/km) for the line plus a 2,500 pW allowance for the terminal equipment (equivalent to 1 pW/km), i.e. a total of 4 pW/km. For the London–New York/Montreal link of about 6,400 km the application of this recommendation pro rata led to a total channel noise of 25,000 pW (−46 dBmOp) being set as an objective. Recent tests of London–White Plains circuits (including compandors, where fitted) gave an average circuit noise of −51 dBmOp, with 95 per cent of the circuits better than the original target of −46 dBmOp.

Routine measurements are made of channel levels. Recent tests of London–White Plains circuits (6,561 km long) gave the following results: mean departure from nominal −0·05 dB, standard deviation about mean 1·49 dB. These figures indicate the high stability of submarine telephone-cable systems.

GROWTH OF OCEAN TELEPHONE-CABLE NETWORK

Since the TAT-1 cable system opened for service in 1956, the ocean submarine-cable network has grown by 54,000 miles (see Fig. 2). A system similar to the TAT-1 system was opened for service in 1959 between the U.S.A. and France (TAT-2). A British-designed single-cable system providing 80 3 kHz-spaced circuits was used for CANTAT (Scotland–Canada), which was completed in 1961, and for COMPAC (Canada–Hawaii–Fiji–New Zealand–Australia), which was completed in 1963. A new 4,000 mile trans-Canada microwave link provided a link to complete the connexion between London and Sydney. In the Atlantic, an American SD system has been laid from the U.S.A. to England (TAT-3) and from the U.S.A. to France (TAT-4). There are now two T.A.S.I. equipments in London and one in Paris, used on circuits to New York. A third T.A.S.I. equipment is to be installed in London for use on circuits to Montreal.

In the Pacific, SEACOM has interconnected Singapore, Jesselton, Hong Kong and Guam, using 80-circuit systems, and Australia to New Guinea and Guam via a new 160 3 kHz-spaced-channel system. SEACOM links up at Guam with the American network from San Francisco to Hawaii, Midway, Wake, Guam, Manila and Japan. Thus, to-day, high-quality circuits are available between London and many points in the Far East.

INTERCONTINENTAL CIRCUIT PARAMETERS

The ever increasing growth of submarine telephone cables has led to the provision of circuits having lengths some 10 times longer than originally envisaged in studies to determine circuit performance. Hence, it has been necessary to take a new look at many of the circuit parameters which were fixed with much shorter circuit lengths in mind. Studies were made to determine new values for noise, attenuation/frequency response, crosstalk and other circuit parameters. These studies have continued within the C.C.I.T.T. and have resulted in many new recommendations for circuit standards. The standards which have been adopted for the Commonwealth cables are as follows.

(*a*) *Noise.* 1 pW/km has been adopted as the target objective for noise. Recent measurements on London–Sydney circuits, 25,800 km in length, show an average noise performance of −47 dBmOp, i.e. 0·8 pW/km.

(*b*) *Circuit Stability.* On transmission paths routed over submarine sections alone, the variation of loss about the nominal value should have a r.m.s. value not exceeding $\sqrt{0{\cdot}3N}$, where N is the number of pairs of

*dBmOp—the ratio, expressed in decibels, of the noise power, measured psophometrically, at a point in a transmission path, to the test level at that point.

†C.C.I.T.T.—International Telegraph and Telephone Consultative Committee.

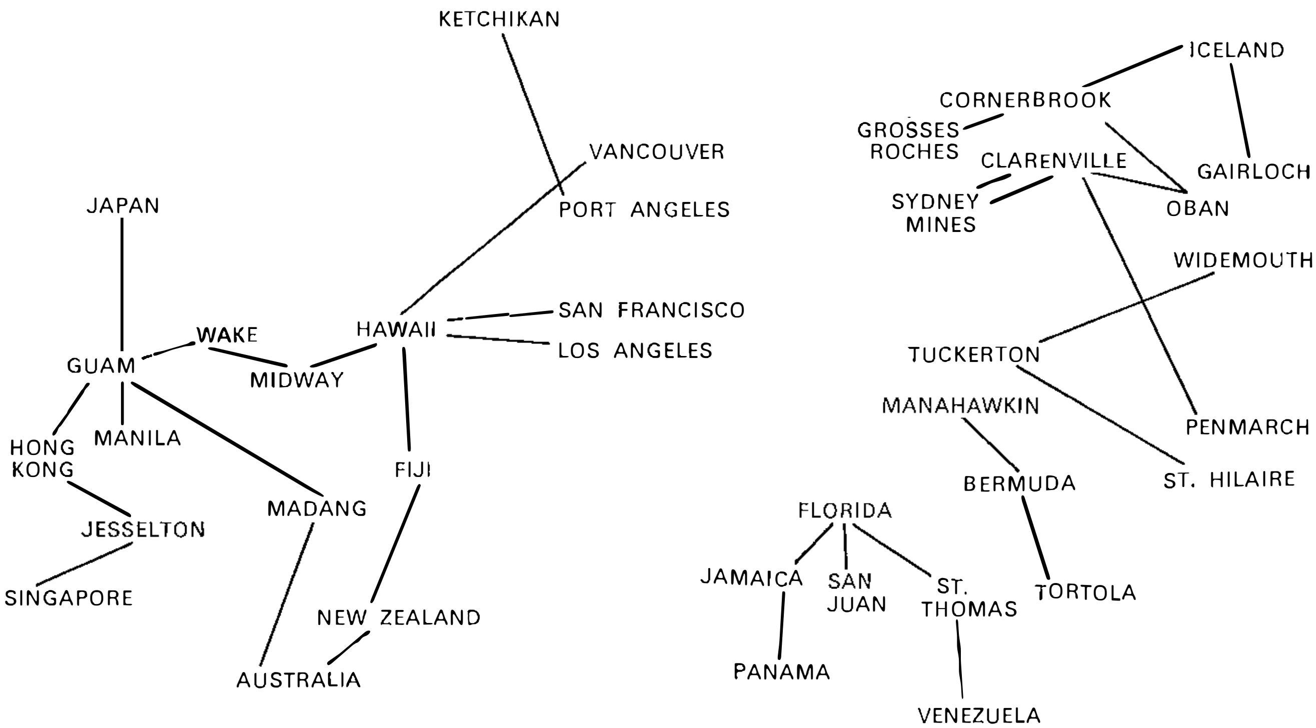

FIG. 2—OCEAN SUBMARINE TELEPHONE-CABLE SYSTEMS

channel-translating equipments. This figure takes into account the inherently stable nature of submarine telephone-cable systems and assumes that very stable channel translating-equipment is used throughout.

(*c*) *Loss/Frequency Response*. For 3 kHz-spaced channels the following figures apply.

300–2,700 Hz: +0·75 to −0·5 dB.
250–300 Hz: +2·25 to −0·5 dB.
2,700–3,000 Hz: +2·25 to −0·5 dB.

For 4 kHz-spaced channels the following figures apply.

300–3,000 Hz: +0·75 to −0·5 dB.
200–300 Hz: +1·25 to −0·5 dB.
3,000–3,400 Hz: +1·25 to −0·5 dB.

(*d*) *Crosstalk*. Crosstalk attenuation between go and return channels should not be less than 43 dB. On very long-distance circuits, e.g. London–Sydney and satellite circuits, the go-to-return crosstalk attenuation must not be less than 55 dB, to avoid the effect of echo.

(*e*) *Frequency Error*. The frequency error depends on the number of interconnected sections, but should not be more than 2 Hz for a 25,000 km circuit.

(*f*) *Spurious Frequencies*. The objective is to ensure that the level of spurious frequencies on any channel band is not higher than −60 dBmO.

The problem of channel loading has also been the subject of review. The C.C.I.T.T. recommendation is based on a long-term mean-power per channel of −15 dBmO, and one multi-circuit voice-frequency telegraph (m.c.v.f.t.) system is allowed in a supergroup. On the short-distance systems to Europe this has proved to be a satisfactory basis. On ocean systems, however, additional factors need to be considered.

The installation of T.A.S.I. equipment increases the activity factor of channels from the normally accepted figure of 0·25 to a figure of 0·75. A larger proportion of the circuits is allocated for data transmission as well as m.c.v.f.t. bearer circuits; one reason for this is the increased time difference, e.g. Sydney is 10 hours ahead of London, resulting in virtually no overlap at all of normal office hours in the two cities, so telegraph services have a big advantage. The demand for non-speech circuits is increasing and could, in the future, require between one third and one half of the total bandwidth. Typical mean powers applied to channels carrying T.A.S.I., telegraph and data signals is −10 dBmO, which suggests that the mean channel-power loading used as a design basis for long submarine-cable systems should be higher than the −15 dBmO used in C.C.I.T.T. recommendations.

MAINTENANCE ORGANIZATION

The length and complexity of modern very long distance circuits on cable and on land lines has posed new maintenance problems, particularly in respect of the maintenance organization needed to enable such circuits to be set up and maintained to standards better than those that had applied to international circuits within the European continent. In addition, semi-automatic and full-automatic working was introduced on international circuits. This development has also increased the problem of maintenance control. As an aid to the solving of these problems the concept of an international network maintenance centre (I.M.C.) was introduced. Each country which terminated international circuits would have one or more maintenance centres. Faults affecting international circuits would be reported to the appropriate centre. The staff at the I.M.C. would then locate the cause of the trouble and take the necessary steps to get the trouble cleared, co-ordinating, where necessary, the efforts of the many maintenance forces at each end of the circuit and spread out at various maintenance points along the length of the transmission path. Hitherto, the maintenance of international circuits had been primarily the responsibility of repeater-station maintenance forces.

The European I.M.C., known as I.M.C./C.[7] (C for Continental), was introduced by the British Post Office in 1956 for its European services when a number of routes were being transferred to semi-automatic working. It was established using the principles given in C.C.I.T.T. Recommendation M71. The British organization set up to co-ordinate the maintenance of the first transatlantic circuits was known as TAT Test. With the provision of additional Atlantic systems, a larger maintenance organization was required, and I.M.C./A. (A for Atlantic) was established. The I.M.C. concept was accepted by all the Commonwealth Partners, and, to-day, I.M.C.s are established where all international circuits terminate. Within the Commonwealth and North Atlantic cable networks an extensive network of service circuits interconnect the I.M.C.s so that the maintenance forces of the I.M.C.s can contact each other quickly, and thus help to reduce the amount of out-of-service time of circuits due to faults.

FUTURE DEVELOPMENTS

What of the future?

In existing ocean telephone-cable systems, there are two supervisory systems[8] for checking the performance of the submerged repeaters. The pulse method relies on non-linearity near the overload point of the amplifier in the submerged repeater to produce the return pulses, with identification of individual repeaters on the basis of transmission time. The advantage of this method is that no additional circuits are neccessary in the repeaters for supervisory purposes, but the disadvantage is that measurement of some repeaters may be very restricted, or even impossible, because of misalignment of the system.

The continuous-tone supervisory system has required a different unit in each submerged repeater. The disadvantage of this arrangement is that all spare units have also to be different. Hence, if there are a number of systems of the same type, the number of spares becomes unnecessarily large. The advantage, however, is that the return signal is produced in a supervisory modulator and does not rely on driving the repeater amplifier near to the overload point. Hence, a reasonable level of return signal is produced even if there is misalignment of the system.

For systems now in production, an improved type of supervisory system is planned incorporating the advantages of both the continuous-tone and pulsed repeater-monitoring systems as used at present, and overcoming the disadvantages mentioned previously. Each repeater will contain a "loop-back" modulator actuated by a pulsed carrier tone sent over the system. The measuring tone will be continuous, and the return pulses will be identified with individual repeaters on the basis of transmission time. All repeaters will thus be identical.

A system having a highest line frequency of about 3 MHz, a capacity of 360 3 kHz-spaced channels, and using valve amplifiers in the submerged repeaters has been developed, and the South Atlantic Cable Company are using such a system for a link between Portugal and South Africa.

Even if it were possible to produce a valve which would be satisfactory for use in a transoceanic repeater of wider bandwidth than a 3 MHz system, the length of such a system would be limited by voltage considerations. This arises from the fact that, as the bandwidth increases, the repeater spacing would become closer, increasing the number of repeaters and, hence, the applied voltage for a given distance. Increasing the voltage causes problems with insulation and the life of high-voltage capacitors over a long period of time. However, it is possible to produce a transistor suitable for use in a transoceanic repeater; furthermore, the lower power requirement of the transistor repeater could mean a reduction in the overall power-feeding voltage, and this aspect may not, therefore, become a limiting factor.

The study and development of long-life transistors suitable for application to submerged-repeaters has been in progress for some time at the British Post Office Research Station. A production unit commenced operation in 1965, and has produced transistors for use in submerged repeaters to be laid in European waters in 1967–68. Emphasis is at present being given to silicon planar transistors[9] as life tests conducted to date have shown these to have reliability of the order required.

A feature of the valve repeater is the need for twin amplifier paths. There is no practicable circuit arrangement for parallelling two transistor amplifiers, but the long-term reliability of transistors makes this unnecessary. The transistor is more prone to damage by voltage surges than the valve. Voltage surges are set up following an interruption (short-circuit, or disconnexion, or one followed by the other) to the power-feeding circuit in the event of a cable fault. The reduced power-feeding voltage due to the relatively small voltage drop across a transistor-type repeater is helpful in this respect, but is partly offset by the greater number of repeaters required at the wider bandwidth. Damage can occur in a microsecond or so, and, thus, protective circuits which are extremely fast in action have been designed.

Systems with a highest line frequency of about 5 MHz are now in production, giving either 480 4 kHz-spaced or 640 3 kHz-spaced channels. One such system is to be laid between the United Kingdom and Portugal, and will link with the Portugal–South Africa system mentioned earlier.

Looking further ahead, systems having greater bandwidth are under consideration; the next step will probably be a 12 MHz system[10] capable of operating over distances up to 4,000 nautical miles and providing 1,080 4 kHz-spaced channels or 1,440 3 kHz-spaced channels. Such systems should be ready for laying by the early 1970s.

For years engineers had dreamt of crossing the Atlantic Ocean with a telephone cable, and in 1956 this dream came true when the opening of the TAT-1 cable provided communication between Britain and North America with the same high quality as obtained on a local call. During the years of patient waiting, engineers perfected their designs to meet the exacting requirements of reliability necessary for the economic operation of oceanic cables. How well they have fulfilled their task can be gauged from the history of performance of the TAT-1 system. The TAT-1 cable has also demonstrated that, if good communication channels are available, people will use them. This fact has encouraged the rapid increase in international communications, so that to-day, little over 10 years from the opening of the first transatlantic telephone cable, people can speak to each other over cable circuits from places as far apart as London and Sydney, London and Hong Kong, or London and Tokyo with the same ease as if speaking to each other in adjacent offices.

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A Television-Network Switching Equipment to 625-Line Colour Standards

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U.D.C. 621.397.74.06

New television-network switching units are being provided by the Post Office in London, Birmingham, Manchester and Carlisle for the Independent Television Authority. The new units are suitable for 625-line colour signals, and a brief description is given of their main features.

INTRODUCTION

To meet the television-routing requirements[1] of the Independent Television Authority (I.T.A.) the interconnexions between the sources and destinations of vision and sound programs have to be changed about 50 times per day at the London network switching centre. Similar changes, although fewer in number, are required at provincial centres. This network switching is carried out for the I.T.A. by the Post Office; the B.B.C. do their own network switching.

A television-network switching equipment[2] was installed in the London Network Switching Centre in 1958, and it is still in use and providing good service. The equipment makes interconnexions at preset times between a number of vision and sound sources and a number of destinations, to meet I.T.A.'s routing requirements. The switching unit was designed for 405-line monochrome signals; its initial capacity was 15 sources and 10 destinations, but it was later extended to cater for 16 sources and 15 destinations. The I.T.A. have now asked the Post Office to provide a new switching unit in London suitable for 625-line colour signals and catering for 30 sources and 40 destinations, with an ultimate capacity of 40 sources and 80 destinations. Switching units of smaller capacity are also required at Birmingham, Manchester and Carlisle. A contractor is designing and installing these units to meet a Post Office performance specification, and this article gives a brief description of them.

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The original switching equipment is virtually two separate units: a sound unit and a vision unit, with separate control panels. Experience has shown that sound and vision are never required separately, so that duplication of controls is not necessary and will not be provided on the new equipment.

A feature of the original switching unit is that, when changes to connexions are to be made, it is necessary to make an entry* of each unchanged connexion, resulting in the entry of much redundant information, e.g. if only one destination-to-source connexion has to be changed then an entry repeating all existing connexions is required, thus increasing the probability of human error. On the new switching unit only changes to connexions are entered.

GENERAL FACILITIES

The switching unit has to provide distribution as well as switching facilities, i.e. it may be required to connect one source to all destinations, or each destination may be connected to a different source. It must be impossible, of course, to connect more than one source to a destination at the same time.

At any time there will be an existing source-to-destination pattern of connexions known as ON AIR. Two stores known as NEXT EVENT and STORE hold, respectively, information defining the time of the next and next-but-one change of pattern, and details of the changes required at those times. Information is at present fed into the stores manually by the operation of push-buttons, one for each source and one for each destination, but provision is made for the addition of an automation module which will control the switching unit by using programs on punched tape or cards. A change of switching pattern

*The operation of programming the equipment to perform a predetermined connexion at a pre-set time is referred to as "making an entry."

occurs when next-event time coincides with the actual time taken from the Post Office speaking clock. Use of the speaking clock as a standard ensures that all studios and switching centres operate to a common time.

Coincidence of next-event time with the actual time causes the changes in the NEXT EVENT store to be transferred to the ON AIR pattern of connexions, and changes in the STORE store with their preset times are transferred to the NEXT EVENT store. A program of further changes may now be entered into the STORE store.

Visual displays of ON AIR, NEXT EVENT and STORE information are required, and revertive signalling is used, i.e. the display information comes from the storage device and not from the manual control.

The following facilities, referred to by their push-button designations, are available for correcting or making late changes to the pre-arranged program.

TAKE ALL: operation of this facility simulates next-event time-coincidence and causes switching to occur immediately.

TAKE ONE is used to connect a destination to the source entered in the NEXT EVENT store in advance of the pre-set time.

HOLD ALL enables switching on time-coincidence to be inhibited. Its use is followed either by operation of the TAKE ALL facility or the entry of a new time for the next switch.

HOLD ONE enables one of the ON AIR connexions to be maintained longer than was planned.

CORRECT NEXT EVENT permits changes to be made to entries of connexions or time in the NEXT EVENT store.

In addition to the other monitors in the control room two picture monitors are provided, one for sources and one for destinations. The same controls are used for selecting sources and destinations for monitoring as are used for entering connexions into the store. A master switch is therefore provided which, as a safeguard against inadvertent misoperation of controls, is normally in the MONITOR position when all facilities except that of being able to select sources and destinations for monitoring are inoperative. When new switching information is to be programmed the master switch is put into the OPERATE position. Very clear visual indication of the mode of the switching unit is given.

DESCRIPTION OF EQUIPMENT

A block schematic diagram of the switching unit is shown in Fig. 1, while Fig. 2 shows the clock system in similar form.

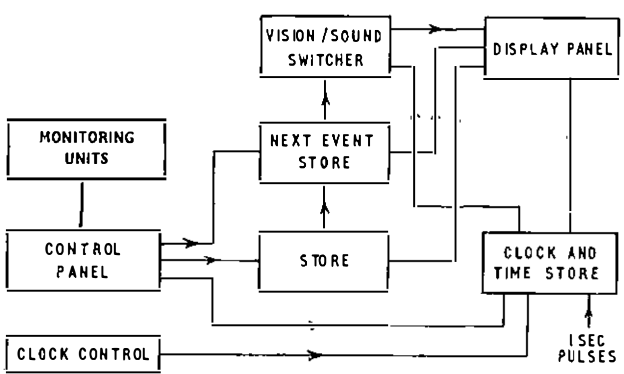

FIG. 1—BLOCK SCHEMATIC DIAGRAM OF SWITCHING UNIT

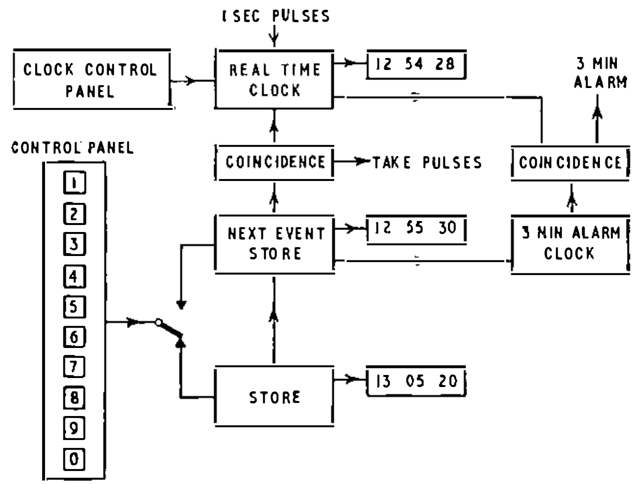

FIG. 2—BLOCK SCHEMATIC DIAGRAM OF CLOCK SYSTEM

Operating Console

The operating console contains the push-button controls. It has sets of SOURCE and DESTINATION push-buttons, and a number of push-buttons and lamps associated with alarm conditions and other facilities. It also contains the source and destination picture monitors, each with lamp indicators and an associated loudspeaker for sound monitoring. Sound and vision monitoring are married, but either the source or destination is chosen for sound monitoring by operation of a 2-position key.

Display Suite

The display suite stands a few feet in front of the operating console, and it displays ON AIR connexions and programmed changes to connexions, together with the pre-set switching times. Three sets of lamp indicators are provided for each destination. The first set identifies the ON AIR source connected to that destination. The second and third sets show changes (if any) to source connexions in the two stores. Two-digit numbers are displayed corresponding to the numbering of the source buttons, each of which is labelled with the complete circuit designation. The display for no connexion is 00 in the ON AIR display, and the store indicators show a blank for no change. Preset switching times for the two stores and the actual time are also displayed.

Vision Matrix

Vision-switching matrices are made up from low-capacitance relays, and each matrix is of 40 sources by 10 destinations. The unit block of the matrix is one output from a 4-outlet source distribution-amplifier feeding a bus bar crossed by 10 destination circuits. The contacts of 10 relays are arranged so that connexions can be made at cross-over points, and 40 such units form a 40-source by 10-destination matrix. Remaining outlets from each source distribution-amplifier serve three other matrices giving access from each source to 40 destinations. A second set of source distribution-amplifiers serving 40 more destinations can be driven by bridging the inputs to the first set of distribution amplifiers, thus achieving the ultimate size of the London switching unit (40 sources by 80 destinations).

Program Matrix and Logic Circuits

The circuits for holding stored information employ motor uniselectors, and one uniselector serves each destination in each store. Multipled bank contacts correspond to sources, and a wiper position marks a future connexion between a source and a destination. A third set of uniselectors controls ON AIR connexions. Sound-circuit connexions are made by uniselector contacts, but vision circuits are switched indirectly by operating relays in the vision matrix. When time coincidence occurs between preset next-event time and the actual time the ON AIR uniselectors drive to contacts marked by NEXT EVENT uniselectors, the latter, in turn, driving to contacts marked by STORE uniselectors. STORE uniselectors do not drive until a new entry is made, but the associated display lamps are extinguished.

Power Supplies

To ensure uninterrupted operation the equipment is battery driven. Certain amplifiers require an a.c. supply, and this is derived from the battery via a static inverter. All stores are non-volatile, i.e. in the unlikely event of a power-supply failure stored information is maintained, ensuring that the switching unit is in the original state when power is restored.

Performance

As four switching units can be included in one long-distance television circuit it was decided that each unit should have a video performance no worse than that of a single minor local link.[3,4] This means that the distortion through a switching unit can be equivalent to about that produced by a 6-mile circuit.

There are two problems which are, perhaps, peculiar to switching devices. The first of these is the possible level variation at any one destination as other destinations are switched to the same source; the resultant variation is required to be no more than that allowed on a minor local link. The second problem is that of crosstalk, particularly at the colour sub-carrier frequency, 4·43 MHz. All switching devices, when open, give rise to crosstalk whose level rises with frequency. The number of crosstalk paths in parallel in a distribution unit depends on the pattern of connexions at any given time, and the effect of the crosstalk depends on how the crosstalk-signal amplitudes add and whether the various paths have the same interfering signal or different signals.

It can be shown that the worst condition is when all destinations take a signal from one source and one different signal is present on all the remaining sources which are not connected to any destinations. This is unlikely to occur in practice. The crosstalk paths in parallel across open connexions are then the product of the number of sources minus one and the number of destinations. As all signals are the same and in phase they add directly, and one open connexion must have a crosstalk performance $20 \log [39 \times 10]$ or 52 dB better than the allowance on a 40-source by 10-destination matrix. The permissible interference at colour sub-carrier frequency is the limiting factor, and this is not known with precision but is about 60 dB. This would require a crosstalk attenuation of 111 dB across an open connexion. Assuming no isolation between matrices this would be increased by 12 dB for four matrices—a very difficult figure to achieve. A more likely condition is with all destinations taking signal from one source and the remaining sources each carrying a different signal. Assuming that the different signals add on a power basis the crosstalk level in one matrix is $20 \log 10 + 10 \log 39 = 36$ dB worse than that from one open connexion, resulting in a requirement of $36 + 60$ dB, i.e. 96 dB, per cross-point and, assuming no isolation between four matrices, a requirement of $96 + 12$ dB, i.e. 108 dB, per cross-point. The switching unit has been specified on this basis. The small relaxations to be obtained from considerations of traffic loading are regarded as a necessary margin against deterioration with time.

The switching units are in course of installation and it is expected that they will be in service in 1967, allowing some time for operating and maintenance staff to familiarize themselves with the new device.

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Book Review

"Mathematics for Electrical Circuit Analysis." D. P. Howson, M.Sc., A.M.I.E.E., A.M.I.E.R.E. Pergamon Press, Ltd. x+170 pp. 72 ill. 17s. 6d.

This book is intended to cover "most of the needs of second and third year undergraduates taking a light-current electrical-engineering course." The range which it attempts to cover is indicated by the chapter headings—Determinants, Circuits Differential Equations, Matrix Analysis, Properties of Linear Networks, Fourier Methods for Harmonic Analysis and The Laplace Transform—Transient Analysis. This wide range is dealt with in a little over 100 pages of actual text, a large proportion of the pages being devoted to exercises at the end of each chapter.

Since minimal knowledge is assumed on the part of the reader it is not surprising that the treatment is somewhat superficial. However, in spite of a certain prolixity in expression it is thought that there are a number of places where the text would not be understood by the readers for whom it is intended, while in other places it is at least misleading if not actually erroneous. For example, in view of the efforts made in Chapter 3 to distinguish between a matrix and a determinant, it is surprising to find the statement on page 2: "Let us now introduce the determinant ,which is a square array of numbers."

There are a large number of books presenting simplified versions of technical mathematics. A very small percentage of such books is useful: this volume does not appear to be one of these exceptions.

T.B.M.N.

Call-Failure Detection Equipment: Interim Equipment for Director and Non-Director Exchanges

J. D. PYRAH†

U.D.C. 621.395.63:658.562

In order to improve the quality of telephone service offered to subscribers emphasis has been directed on reducing the "no-tone" failure rate within the local automatic telephone network. A scheme has been devised in which live traffic is continuously sampled and observed, to detect and locate, as speedily as possible, those calls which fail. Until such time as standard comprehensive call-failure detection equipments become available, interim equipment with limited facilities has been provided. This article describes the interim arrangements provided in director and non-director exchanges.

INTRODUCTION

THE quality of service offered to telephone subscribers is always a subject for concern by both the public and the Post Office, and criticism has, in recent times, been levelled at the number of telephone calls that fail to mature for one reason or another. Because "no-tones" are the cause of a large proportion of complaints, emphasis has been directed on reducing this type of failure in an effort to improve the quality of service. Initiative has been shown by maintenance staff within various Regions in the development and production of devices designed to observe telephone traffic with the primary object of detecting those calls which fail to receive a tone on completion of dialling. A team from the Engineering Department maintenance branch examined the facilities and utility offered by these Regional devices, and from the information gleaned, planned the development of a standard comprehensive item.

However, as the development of such an item takes time, interim designs based upon Regional devices have been developed and arrangements made to supply them in sufficient quantity to meet maintenance requirements; both these and the standard items will be known as call-failure detection equipments.

To obtain the maximum benefit from such equipment, the selection of an observation point within an exchange trunking scheme and the rate of sampling the traffic offered at that point are of great importance. Early-choice subscribers' 1st selectors have been chosen as the observation point in non-director exchanges, enabling originated calls, irrespective of their routing, to be observed.

For the non-director interim call-failure detection equipment use has been made of the existing centralized service observation (C.S.O.) sampling equipment, which already has access circuits connected to the required selectors together with the appropriate control circuits for sampling calls at a high rate. For director exchanges, the director has been chosen as the observation point for the interim call-failure detection equipment, enabling a large number of originating calls to be observed. The equipment is associated with a director serving a particular A-digit selector level and, during the initial stages, is periodically moved from one A-digit selector level to another so that complete coverage is given on all originated traffic.

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NON-DIRECTOR EXCHANGES

The C.S.O. equipment[1,2] is a means of sampling telephone traffic for the purpose of measuring the quality of the service. For each exchange observed, access and selector-tapping equipments are provided which are connected to a central observation position, via a junction if necessary. The call-failure detection equipment for non-director exchanges is connected to the C.S.O. selector-tapping and outgoing-signalling circuit, the associated access equipment being switched to the subscribers' 1st selectors so that observations may be made at this point.

The prime functions of the call-failure detection equipment are:

(*a*) to observe on calls to the home or adjacent exchanges for the purpose of detecting those calls which fail to receive a tone on completion of dialling,

(*b*) to provide a means of holding a failed call so that the cause of the failure may be ascertained,

(*c*) to provide a "service-measurement" facility in which call failures are registered but the switching equipment is not held, enabling a measure of the exchange no-tone performance to be produced, and

(*d*) to observe calls at the same time as, or separately from, the C.S.O. operator.

To select calls routed to the required exchanges, digit discrimination is provided; calls not selected are excluded from further observations, e.g. calls to the subscriber trunk dialling (S.T.D.) network and to the emergency services. Adjustment of the selection may be made by alteration to wire strappings.

On receipt of the last digit, a tone receiver is connected to detect the presence of a tone. If busy, ringing or number-unobtainable (N.U.) tone is detected the call is regarded as successful and registered on a meter, the observation equipment releasing to await a further call. Calls failing to receive a tone within a pre-determined time may be held for the switching equipment used to be traced and for fault-clearance purposes. In this event, the calling-subscriber's line equipment, the observed selector, and other forward-routed selectors are prevented from releasing and the exchange prompt alarm is given. Because the calling-subscriber's line equipment is held by the call-failure detection equipment the calling subscriber loses control of the call and is temporarily unable to make further calls. However, the maintenance engineer dealing with the fault enters the circuit and informs the caller that a fault has been detected on the switching equipment and requests his co-operation pending removal of the holding condition from the caller's line. The call is back-traced to release the subscriber's line equipment and then forward-traced to locate the cause of failure. To facilitate forward-tracing, a digit display can be connected to provide an immediate visual indication of the number dialled. Should the held call not receive attention within a predetermined time, hold conditions are removed from the observed selector, returning control of the call to the subscriber.

A printer[3] associated with a line-signal monitoring unit[4] may be connected to the call-failure detection equipment for recording the digits dialled by the subscriber; for an unsuccessful call, a distinctive symbol is also printed. These recordings provide the essential information needed for future reference and analysis under the service-measurement facility.

DIRECTOR EXCHANGES

The call-failure detection equipment for director exchanges is connected to a suitably modified director. For each call that is received by the director, outgoing-line continuity and polarity tests are applied by the equipment during the interdigital pauses following transmission of each routing and numerical digit. When digit transmission is completed, a tone receiver is connected to the line, and the director is held pending the detection of tone. If a tone (busy, ringing or N.U.) is detected, the call is regarded as successful and registered on a meter; the director is then allowed to release.

However, under the "hold" facility, if a line fault or a no-tone condition is detected, forward-holding conditions are applied to the line and the director is prevented from releasing. The fault is registered on a meter and exchange alarms are given, together with a lamp display indicating the nature of the fault.

To assist in forward call-tracing and fault clearance, the number dialled can be obtained by reference to the director code and numeral storage switches, while the exact switching stage at which the call failed can be ascertained from the position of the director send-control switch wipers.

Because the call-failure detection equipment is holding the director, the associated 1st code selector and calling-subscriber's line equipment are also held and the calling subscriber temporarily loses control of the call. The call is traced, held at an alternative switching stage and the calling subscriber informed by the maintenance engineer that a fault has been detected on the switching equipment. The caller is asked to co-operate pending removal of the holding condition from his line. Control is then restored to the caller by back-tracing to, and manually releasing, the line equipment.

If this tracing is not completed within a reasonable time, forcible-release conditions are established in the director. This results in the release of the director, A-digit selector and other forward-routed selectors, while returning control of the 1st code selector and line equipment to the caller.

Because non-standard line conditions are encountered during the establishment of calls to such services as WEAther, ASK and 246, and to prevent holding call failures routing to emergency services (code 999), discrimination has been provided to prevent testing on these calls. On code-only calls, other than 999 (e.g. TIM), line-polarity and continuity tests are applied, but, because ringing tone may not be encountered on such calls, the test for tone reception is prevented. A service-measurement facility is provided whereby the holding of call failures is prevented following meter registration and the director is released.

As for the non-director exchange equipment, a printer, associated with a line-signal monitoring unit, may be connected to the director outgoing-line wires to record the digits transmitted by the director. Provision has been made to indicate on the printer tape those calls for which testing was unsuccessful. If a fault (line or tone) had been detected, a distinctive symbol is printed adjacent to the last recorded digit, thus indicating the switching stage at which the fault occurred.

The printed information provides a means for analysing the results obtained under the service-measurement facility.

CONCLUSIONS

Continual observations of live telephone traffic makes it possible to detect and locate those plant faults that are directly affecting the service, allowing maintenance staff to clear faults sooner than is possible by the present routine methods. The time a fault remains in the system is, therefore, reduced, and, consequently, the service is greatly improved.

In addition, up-to-date statistics of the quality of service given to subscribers for calls within the local telephone network can be produced. Call-failure detection equipments, both of the type described and the forthcoming more complex equipment having improved facilities, are expected to prove an effective maintenance aid in both of these roles.

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Book Review

"Space Communications Techniques." R. P. Filipowsky and E. I. Muehldorf. Prentice Hall Technology Series. xi+333 pp. 55 ill. 104s.

This volume, by the same authors as "Space Communications Systems," provides a largely descriptive presentation of components for spacecraft communications and of space-communications sub-systems. A considerable part is devoted to particular spacecraft with photographs and schematic illustrations, and, while valuable, is bound to become dated in a short time. Very extensive amplified bibliographies are appended to the two main chapters and, in fact, these occupy 142 pages of the text.

The book forms a useful supplement to the larger volume on systems and should be of particular interest for reference purposes by circuit, component and sub-system designers.

J.K.S.J.

The PVR 800 High-Frequency (3–30 MHz) Radio Receiver

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U.D.C. 621.396.62.029

The transistor-type receiver described is of the quadruple-superheterodyne type and employs digital techniques to synthesize the conversion-oscillator frequencies and switched band-pass filters to obtain radio-frequency selectivity. It is primarily intended for the long-distance point-to-point h.f. radio services and gives a choice of any six pre-set frequencies in the 3–27·5 MHz band. Provision is made for extended or remote control, and the modular construction aims at easing maintenance and facilitating the manufacture of different versions of the receiver for the reception of independent-sideband or frequency-shift signals, with or without spaced-aerial diversity.

INTRODUCTION

DIFFICULT reception conditions exist, due to congestion, in the 3–30 MHz fixed-service bands, and, in spite of the amount of traffic being transferred to submarine-cable and satellite circuits, there seems little likelihood of any easing of the situation in the forseeable future. Apart from the need to contend with the vagaries of the ionosphere, difficulties also arise from the operation of a large number of high-power transmitters with small frequency separation. The reception of wanted low-level signals in the presence of a number of adjacent high-level signals necessitates a high degree of linearity in the receiver, with good selectivity and with a noise level that is low compared with route noise from the aerial. In addition, any variations in the frequency of the transmission must be closely followed by the receiver without its tuning being affected by noise and interference.

Against this background there is the need to reduce operating and maintenance costs to a minimum, and, hence, the equipment must be designed for reliable fault-free service and simplicity of operation, with the smallest practicable need for human intervention.

In the Plessey PVR 800 series of receivers the exclusive use of semiconductors in place of thermionic valves, and the use of low operating voltages, printed circuits, and good quality components, with vigilant inspection and testing, all tend to produce the high standard of reliability required. Simplicity of operation is facilitated by the provision of synthesized conversion-oscillator frequencies, pre-set frequency selection, automatic search for the wanted signals, and the virtual absence of manually-operated controls.

A great advantage of the modular method of construction employed in these receivers is the ease with which the make-up of receivers can be varied to suit a variety of needs. However, this article is, in the main, concerned with the independent-sideband receivers produced for the British Post Office h.f. point-to-point services, the main requirements of which are as follows.

(*a*) Frequency range: 3–27·5 MHz.
(*b*) Type of reception: independent sideband (A3B), with alternative versions of the receiver for double sideband (A3) and telegraphy (F1, F6).
(*c*) Remote selection of any six pre-set frequencies.
(*d*) Automatic search for the wanted carrier within ± 300 Hz of the selected pre-set frequency.
(*e*) Automatic frequency control to within ± 3 Hz.
(*f*) Synthesis of conversion-oscillator frequencies from a stable frequency source.
(*g*) Noise figure: 8–10 dB.
(*h*) Flat automatic-gain-control characteristic.
(*i*) High signal-handling capacity and selectivity.
(*j*) Suitability for single-aerial or spaced-aerial diversity reception.
(*k*) Operation from 21–28-volt d.c. supply.
(*l*) Use of semiconductors.

No restrictions were placed on the types of circuits to be employed, but 51-type panel construction in conjunction with an Apparatus Rack No. 52 was required.

OUTLINE DESCRIPTION

A simplified block schematic diagram of the independent-sideband non-diversity version of the receiver is shown in Fig. 1.

It will be noted that the basic design philosophy differs in a number of respects from that used in conventional receivers. The input circuit is unusual in that the 3–27·5 MHz range is split into six bands by means of fixed band-pass filters, no variable tuning elements being employed. Alternative first intermediate frequencies of 39·3 or 34·3 MHz are selected, depending on the required input signal-frequency. The use of such "above-band" first intermediate frequencies gives good image rejection, an unrestricted lower limit to the signal-frequency range, and allows the first conversion-oscillator frequency to be always above the highest signal-frequency. Subsequent intermediate frequencies are at 10·7 MHz, 2·6 MHz and 100 kHz, sideband selection being effected at the latter frequency. Conventional automatic gain control (a.g.c.) operates only on the 2·6 MHz intermediate frequency (i.f.) amplifier, but, to avoid overloading of the preceding fixed-gain stages by high-level signals falling within the selected band, attenuation is automatically inserted as required at the receiver input.

On selection of a new frequency the receiver will search over a ± 300 Hz range until a carrier having an acceptable signal-to-noise ratio is encountered. Search then ceases and the automatic-frequency-control (a.f.c.) system takes over. A.F.C. action is inhibited while the carrier-to-noise ratio is too low, and this is effective in preventing false hunting when radio conditions are poor. The a.f.c. system itself is novel in that it compares the time occupied by a fixed number of cycles derived from the incoming signal with that occupied by the same number of cycles derived from the reference frequency. The resulting information is used to control a motor-driven capacitor, and, thus, to adjust the frequency of the 2·7 MHz conversion oscillator in the required sense to reduce the tuning error to less than 3 Hz.

Frequency synthesis of the first conversion-oscillator frequency, which is in the range of 42·3 to 66·8 MHz (in 125 Hz steps), is effected in two stages. Firstly, a frequency in the range 2·3 to 3·3 MHz is synthesized

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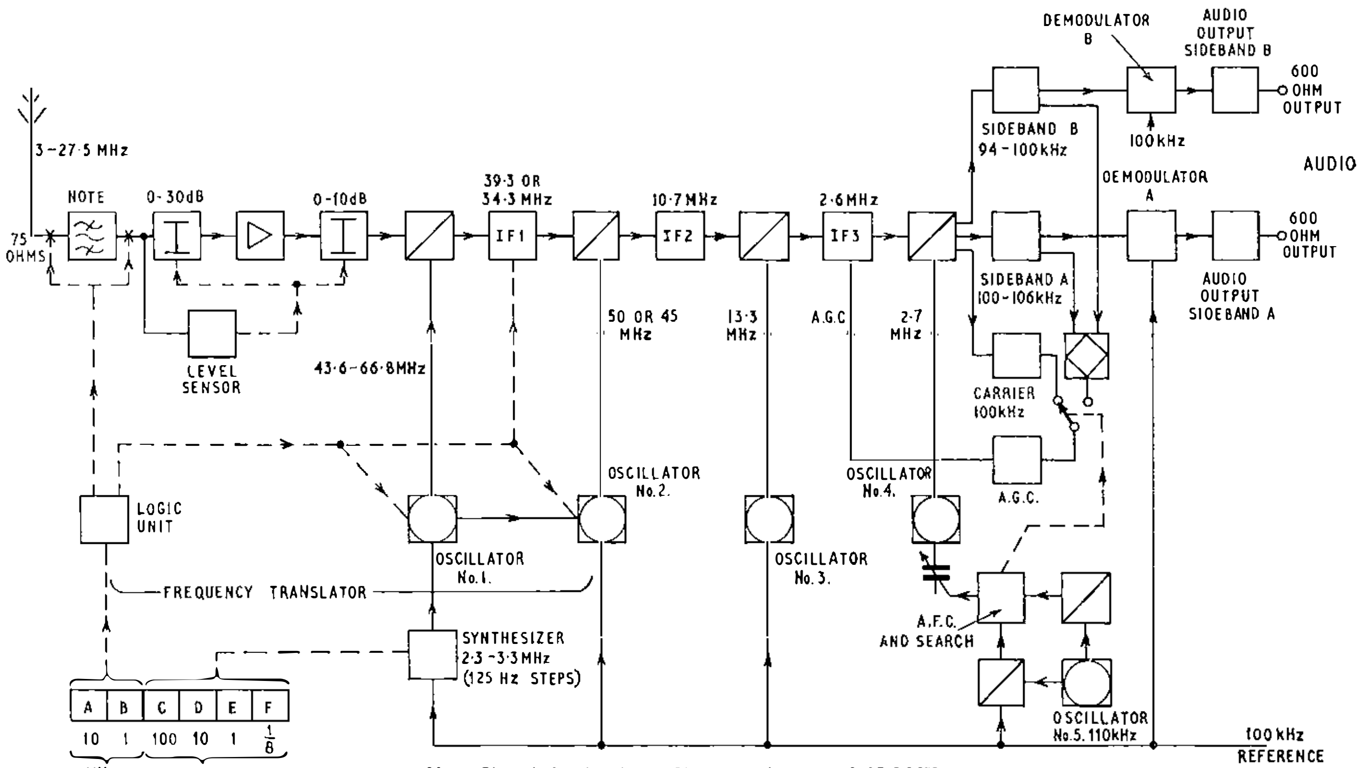


Note: Six switched band-pass filters covering range 3–27·5 MHz

FIG. 1—BLOCK SCHEMATIC DIAGRAM OF PVR 800 RECEIVER

from the 100 kHz standard, using "add and divide" principles. Frequencies in 1 MHz and 5 MHz steps, in the ranges 14·9 to 18·9 MHz and 55·9 to 80·9 MHz, respectively, are then added. Free-running crystal-controlled oscillators are used for these steps, and the frequency errors introduced are cancelled out by adding the same errors to the second conversion frequency (45 or 50 MHz). This arrangement for the derivation of the first and second conversion-frequencies produces the same result in terms of frequency accuracy, at the output of the second mixer, as if each frequency had been directly derived from the 100 kHz standard.

The receiver uses modular construction,[1] and of particular interest is the large-scale use of a standard low-noise wide-bandwidth directly-coupled 20 dB amplifier, in conjunction with frequency-determining networks where gain and selectivity are required, or alone when gain only is required.

Mechanically, the receiver conforms in general to British Post Office 51-type practice with the panels mounted in an Apparatus Rack No. 52. Overall dimensions are 7 ft 3 in. high, 1 ft 9⅝ in. wide and 2 ft 1¾ in. deep. Connexions from 51-type panel units to the rack wiring are made by means of standard bridging links incorporating coaxial plugs and sockets where required. One panel unit normally houses a number of printed-circuit modules, each contained in its separate extruded aluminium screening box. Module-to-panel connexions are by printed-circuit connectors, and all high-frequency inter-panel connexions are made at 75 ohms nominal impedance, with large-scale use of miniature coaxial plugs and sockets.

Provision is made in the PVR 800 receiving system for mains-driven power supply units, but, for the receivers for Post Office use, power is supplied by external secondary batteries, continuously float-charged by voltage-controlled mains-driven rectifier units. The main receiver supply is at 21–28 volts d.c. with an auxiliary supply at 50 volts for the operation of relays and similar items. Voltage regulation is provided in the receiver in two stages: a pre-regulator and module stabilizers.

No manually-operated tuning devices are employed in the receiver other than the six sets of digit roller switches in the synthesizer memory unit. These switches allow the pre-setting of six radio frequencies anywhere in the band 3–27·5 MHz, activation of the required pre-set frequency normally being effected at a central control position.

DETAILED DESCRIPTION

The various functional parts of the receiver shown in block form in Fig. 1 are described in more detail in the following paragraphs.

Signal Path

The input signals from the aerial pass through one of the six band-pass filters, covering 3–27·5 MHz in the sub-octave bands 3–4, 4–6, 6–9, 9–13, 13–19 and 19–27·5 MHz, the required filter being selected by reed relays operated from the synthesizer and frequency-translator logic unit, which at the same time selects the appropriate first i.f. filter (34·3 or 39·3 MHz) and the consequent second conversion frequency (50 or 45 MHz).

The aggregate signal level at the output of the selected band-pass filter is monitored, and, if a predetermined level is exceeded, up to 40 dB of attenuation is introduced in 10 dB steps; to maintain the noise factor the initial 10 dB of such attenuation is inserted after the first amplifier, the remaining 10 dB steps being inserted prior to the amplifier. The overall dynamic range thus obtained extends from noise level to + 115 dB relative to 1 μV, allowing the efficient handling both of low-level signals, which require the best noise figure, and high-level signals, where linearity is more important. These techniques enable fixed-band radio-frequency selectivity to be used.

The signals, after passing through the selected band-pass filters, are amplified and applied, via 30 MHz low-pass and i.f. rejection filters, to the first frequency changer. The first conversion-frequency, in the range 42·3 to 66·8 MHz (in 125 Hz steps), is derived from the synthesizer and frequency-translator unit and is amplified before being mixed with the incoming signals to produce a first intermediate frequency of either 39·3 or 34·3 MHz. The use of alternative i.f.s has been adopted so as to avoid certain troublesome intermodulation components produced in the mixers. The signal is then filtered, amplified, and passed through a 43 MHz low-pass filter, to reject the upper-sideband products of the frequency-changing process. The choice of the i.f. is automatically made in the logic circuits associated with the six sets of frequency selectors located in the memory unit.

The i.f. signal is mixed with the 45 or 50 MHz conversion frequency to produce the 10·7 MHz second intermediate frequency. After filtering in a band-pass filter centred on 10·7 MHz to select the 12 kHz bandwidth required for independent-sideband operation, the 10·7 MHz second i.f. signal is mixed with a 13·3 MHz conversion frequency synthesized from the 100 kHz standard, a 4 MHz low-pass filter removing the unwanted upper-sideband product of the mixing process. The resulting 2·6 MHz third intermediate frequency signal is amplified before connexion to the main 2·6 MHz amplifier unit.

The signal input, at 2·6 MHz, passes through a band-pass filter and two amplifier modules to the frequency changer. The associated 2·7 MHz conversion-frequency oscillator incorporated in the unit is servo-controlled over a maximum range of ± 450 Hz by control signals received from the automatic-frequency-control (a.f.c.) and signal-search modules mounted in other units.

The signal output (at 100 kHz) then passes to the 100 kHz amplifier units, and to the appropriate crystal filters for splitting the signal into the upper-sideband (100–106 kHz), lower-sideband (94–100 kHz) and pilot carrier (100 kHz) components.

The separate upper-sideband and lower-sideband signals are demodulated against 100 kHz, directly derived from the 100 kHz reference frequency. Auxiliary outlets are provided at this point for feeding a telegraph demodulator and its associated a.f.c. system.

Automatic Gain Control

To provide the a.g.c. information the 100 kHz pilot carrier is filtered, amplified and rectified in a detector whose d.c. output is linearly proportional to the level of the r.f. signal. The 2·6 MHz amplifier, to which a.g.c. is applied, has a logarithmic control-voltage/attenuation characteristic, and to compensate for this the controlling d.c. is passed through a logarithmic shaping network using transistors as non-linear series elements. The resulting overall a.g.c. reduces a change of 80 dB in r.f. input level to less than 5 dB at the audio-frequency output.

Automatic Frequency Control

Three separate functions are performed in the a.f.c. unit: firstly, the normal one of ensuring that the audio output of the receiver is within the required ± 3 Hz of its correct frequency; secondly, automatic search; and, thirdly, the recognition of carriers having an acceptable signal-to-noise ratio. As a corollary, it also inhibits the a.f.c. function when the signal-to-noise ratio of a captured carrier falls too low for effective control and discriminates between carriers and modulated signals.

The a.f.c. functions on the basis of comparing a signal, obtained from the 100 kHz reference frequency, with a signal derived from the received carrier (at nominally 100 kHz), and establishing the sign and magnitude of the difference frequency, i.e. the error. The appropriate change is then automatically made to the frequency of the 2·7 MHz conversion frequency oscillator to reduce the frequency error to within ± 3 Hz. To prevent unnecessary rapid hunting of the system, correction is effected at a rate not exceeding 1 Hz/second. A simplified block schematic diagram is shown in Fig. 2.

The nominally 100 kHz carrier signal and the 100 kHz reference frequency are both converted to 10 kHz using a common 110 kHz conversion-frequency oscillator, and are connected to a gate which is switched at 50 Hz. The resulting output signal from the gate thus consists of alternate 10 ms elements of reference and carrier signals. Commencing approximately 2·5 ms after the start of each element, a fixed capacitor is allowed to charge from a constant-voltage source during the time occupied by 4 Hz of the signal (reference or carrier). The resulting voltage is then transferred to, and stored on, a second capacitor, the first being discharged ready for the next element (carrier or reference). The voltage across this second capacitor will always be of the same value for the 4-cycle periods of reference, but for the 4-cycle periods of carrier frequency it will be larger, equal to, or smaller, depending on whether the carrier frequency is lower, equal to, or higher than its correct frequency.[2] By means of pulse-stretching, amplification and d.c. restoration techniques the stored information is converted into a train of 10 ms pulses, which represent, by their amplitude and polarity, the magnitude and direction of the frequency error.

After integration the pulse train is used to control, by means of a ring modulator, the amplitude and phase (0° or 180°) of a 400 Hz signal connected to a motor driving the tuning capacitor in the 2·7 MHz conversion-frequency oscillator. Velocity feedback is employed to prevent excessively high rates of error correction.

The carrier-to-noise ratio is continuously monitored in a circuit of novel concept, utilizing double rectification of the 100 kHz carrier signal. The first rectification produces a d.c. output corresponding to the mean signal level, and, the second, a d.c. output corresponding to the fluctuation due to noise or modulation on the signal. These two outputs are applied to a comparator circuit, which controls a trigger-operated gate to inhibit the a.f.c. action when the signal-to-noise ratio falls below a selected value (typically 7–8 dB).

When a change is made from one pre-set frequency to another it is undesirable that manual assistance should be needed to enable the a.f.c. to lock-on to the new signal, which either may not be present at the time the change is made, or may not be precisely on its assigned frequency.

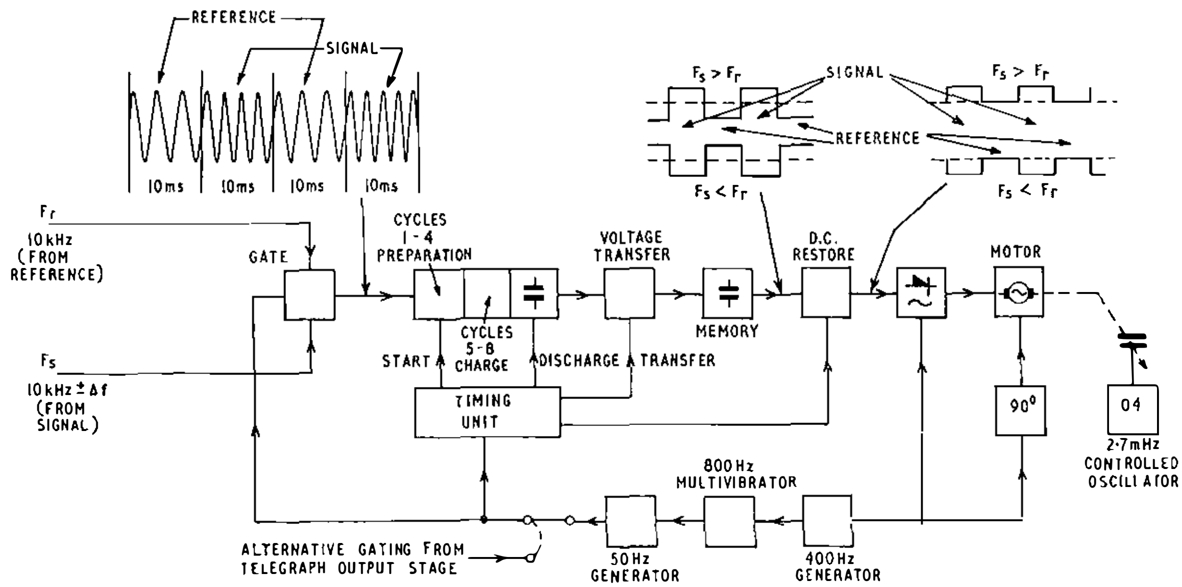


FIG. 2—AUTOMATIC FREQUENCY-CONTROL SYSTEM

To cater for these contingencies the receivers are equipped with automatic-search and carrier-recognition facilities. Thus, when a change of pre-set frequency is made it initiates automatic search over a range adjustable up to a maximum of ± 450 Hz (± 300 Hz for British Post Office use). The search continues at a rate of one sweep per minute until a steady signal, having a signal-to-noise ratio better than the a.f.c.-inhibit value, is encountered (e.g. 7 dB).

Synthesizer and Frequency-Translator Unit

With the exception of the 2·7 MHz oscillator, which is under the control of the a.f.c. and signal-search facilities, and the 110 kHz oscillator used in the a.f.c., the frequency of all the conversion oscillators is effectively controlled by the 100 kHz reference signal.

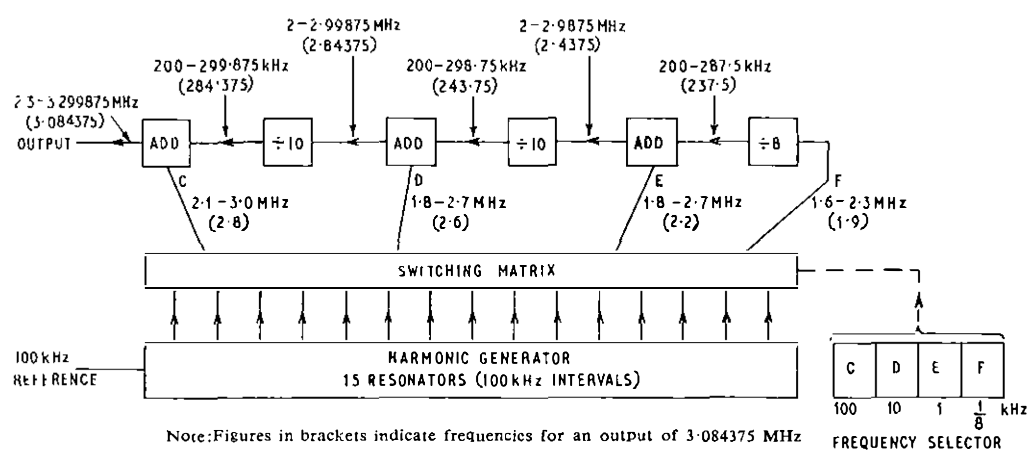
To produce the first intermediate frequency of 39·3 or 34·3 MHz a conversion frequency in the range 42·3 to 66·8 MHz is required. This frequency is produced by combining the output of the synthesizer,[3] which generates the frequencies in steps of 125 Hz over the range 2·3 to 3·3 MHz, with frequencies at 1 MHz steps in the range 40to 64 MHz.

A simplified block schematic of the synthesizer is shown in Fig. 3. Fifteen separate crystal resonators (1·6 to 3·0 MHz in 100 kHz steps) are energized by the 100 kHz reference frequency, and operation of the C, D, E and F frequency-selector switches (marked in "signal" frequency) causes the switching matrix to select the four frequencies which, by successive processes of division and addition produce the required frequency in the range 2·3 to 3·3 MHz.

The frequency translator in which frequencies at 1 MHz steps are produced and combined with the synthesizer output (see Fig. 4) employs six crystal-controlled oscillators at 5 MHz intervals in the range 55·9 to 80·9 MHz, and five crystal-controlled oscillators at 1 MHz intervals in the range 14·9 to 18·9 MHz. The required first conversion frequency (01) is produced as follows:

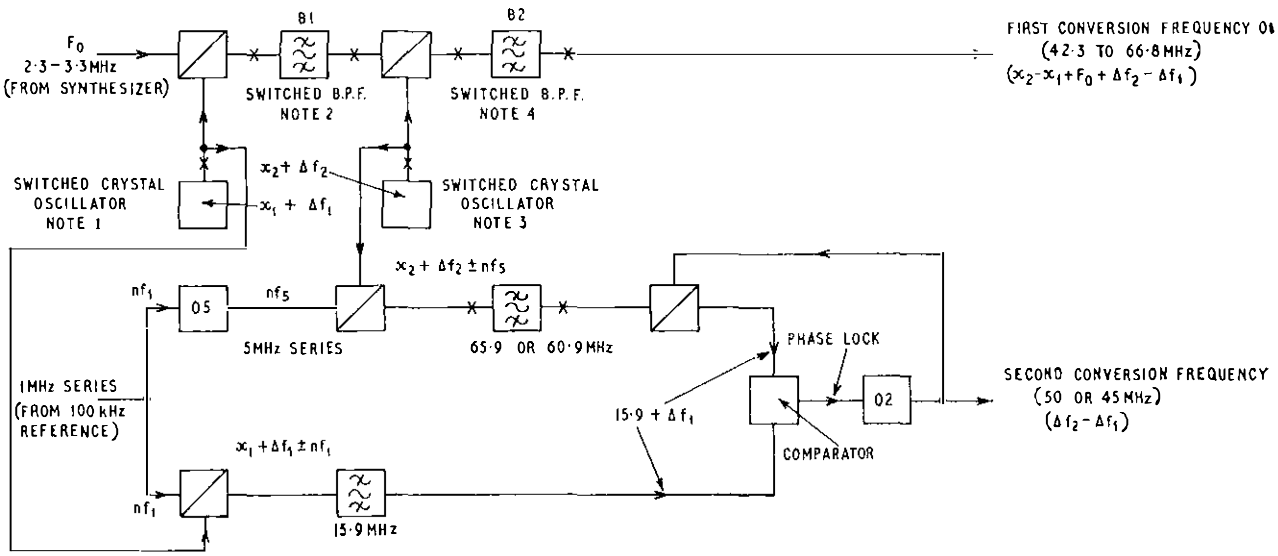
$$01 = x_2 - x_1 + F_0 + \Delta f_2 - \Delta f_1$$

where x_2 = 55·9, 60·9, 65·9, 70·9, 75·9 or 80·9 MHz,
x_1 = 14·9, 15·9, 16·9, 17·9 or 18·9 MHz,
F_0 = 2·3–3·3 MHz in 125 Hz steps,
Δf_2 is frequency error of x_2, and
Δf_1 is frequency error of x_1.



Note: Figures in brackets indicate frequencies for an output of 3·084375 MHz

FIG. 3—FREQUENCY SYNTHESIZER



Notes:

1. Oscillator frequencies: 14·9, 15·9, 16·9, 17·9 or 18·9 MHz.
2. Filter pass-bands: 11·6–12·6 MHz, 12·6–13·6 MHz, 13·6–14·6 MHz, 14·6–15·6 MHz, or 15·6–16·6 MHz.
3. Oscillator frequencies: 55·9, 60·9, 65·9, 70·9, 75·9 or 80·9 MHz.
4. Filter pass-bands: 39·3–44·3, 44·3–49·3, 49·3–54·3, 54·3–59·3, 59·3–64·3 64·3–69·3 MHz.

FIG. 4—GENERATION OF FIRST AND SECOND CONVERSION FREQUENCIES

It will be apparent that the output frequency contains the frequency errors of the crystal oscillators used, but these errors are cancelled out by employing the same oscillators in the derivation of the second conversion frequency (45 or 50 MHz). This is shown in the lower part of Fig. 4.

A serious problem in synthesizer generation of frequencies is the elimination of the unwanted products of the synthesizer processes, which may produce undesirable responses in the receiver. In the PVR 800 receiver the unwanted products are, in general, adequately suppressed by the use of narrow-band crystal filters backed up by active filters using the "phase-locked loop" principle. There are, however, a few specific frequency components which have required the insertion of individual simple *LC* circuits to achieve acceptable suppression.

TYPES OF SIGNAL DEMODULATION

A number of different configurations of receiver are available, depending on the type of emission to be received. In the main, differences are in the 100 kHz and subsequent sections of the receiver.

Independent-Sideband Emissions

The separation of the upper and lower sidebands by means of crystal filters has been mentioned earlier. After amplification, the output from the sideband-path filter is mixed with the local 100 kHz reference frequency in a demodulator which employs balanced circuit arrangements for both reference-frequency and sideband inputs. This results in almost complete suppression of the demodulation carrier and the 94–99·8 kHz or 100·2–106 kHz sideband components, the demodulator output nominally consisting of audio frequencies in the range 200–6,000 Hz.

The audio-output amplifier includes a filter to remove any residual high frequencies, followed by a conventional 3-stage directly-coupled amplifier providing a 600-ohm output impedance. The amplifier has a maximum output of + 14 dBm before overloading occurs, providing an 8 dB overload margin. A headphone monitoring facility is provided at this point.

The circuits arrangements as regards demodulators and output amplifiers are identical for the upper and lower sidebands.

Frequency-Shift Telegraphy Reception

There are several different systems of frequency-shift telegraphy in current use on radio circuits. Multi-channel systems providing up to 12 or 15 100-baud telegraph channels are normally aggregated as single sideband emissions, separation and demodulation of the individual channels being effected in equipment external to the receiver itself. Diversity reception is invariably used for telegraphy, but apart from this, as far as the receiver is concerned, these emissions are treated no differently from telephone emissions.

Single-channel or diplex (4-tone) frequency-shift systems are catered for by fitting an additional unit (telegraph demodulator) to the receiver. In the single-channel system (F1) one radio frequency indicates one telegraph condition, the frequency being changed by 100, 200 or 400 Hz to indicate the other condition. The same unit caters for the diplex (F6) system, which employs three stages of shift (200, 400, 600 Hz or 400, 800, 1,200 Hz) to indicate the four possible conditions of the two telegraph channels, in conformity with the recommended code.

In the telegraphy versions of the PVR 800 receiver, all the signal-carrying modules from the h.f. amplifier to the 100 kHz amplifier are duplicated. The conversion-frequency oscillators, a.f.c., etc., are common to both diversity paths. Each telegraph demodulator provides separate filtering for two tones; thus, for single-channel frequency shift (F1) dual-diversity reception, two demodulators are fitted. Diplex (F6) dual-diversity reception requires four demodulators. Each demodulator accepts a 100 kHz signal output and converts this to 10 kHz plus (or minus) half the frequency shift. Narrow-band filters, having a choice of bandwidths suitable for 100-baud, 200-baud or 300-baud working, select the tone frequencies. The outputs from the two diversity paths are combined and rectified in an assessor circuit. [4, 5, 6] The d.c. output, which is in polar form, is further amplified to produce $\pm$ 6-volt signals. An additional 10 kHz output, derived from the "mark" or "space" filter, is used for a.f.c.

OPERATING FEATURES

It will be apparent from the foregoing description that the design of the PVR 800 receiver is primarily aimed at minimizing the manpower required for day-to-day operation. The only external controls on the receiver itself are the six banks of frequency-selection switches (plus one bank for local operation), and the variable attenuators for controlling the level of the sideband output signals sent to line.

CONCLUSIONS

Considerations of space have allowed only brief descriptions of some of the many interesting features of the PVR 800 series of receivers, but some indication has been given of the ways in which the design differs from that of older receivers. It will be apparent that the number of components involved in the receiver is much greater than in the earlier manually-operated types, but, with semiconductor techniques and conservative rating of components, the overall reliability should, nevertheless, be appreciably better than has been achieved in the past.

ACKNOWLEDGEMENT

Acknowledgement is made to The Plessey Company, Ltd., who designed and developed the PVR 800 receiver, for permission to publish this information.

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[1]PERKINS K. G. A Modular Approach to the Design of H.F. Communications Equipment. I.E.E. Convention on H.F. Communication, Mar. 1963.

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[3]PERKINS, K. G. An Integral Synthesizer used in a High-Grade H.F. Receiver. Conference on Frequency Generation and Control for Radio Systems, *I.E.E.*, May 1967. Patent No. 1036727.

[4]ALLNATT J. W., JONES, E. D., and LAW, H. B. Frequency Diversity in the Reception of Selectively. Fading Binary Frequency-Modulated Signals. *Proceedings I.E.E.*, Vol. 104, Part B, Mar. 1957.

[5]Patent Specification 832184.

[6]Patents No. 1074514 and 1072261.

Book Reviews

"Short-Wave Listening." J. Vastenhoud. Iliffe Books, Ltd. 107 pp. 33 ill. 12s. 6d.

This is another book in the Phillips Paperbacks series which the publishers have prepared for interested lay-men and keen amateurs on the various branches of radio and electronics. This particular book, of just over 100 pages, reviews at popular-science level the development of short-wave broadcasting and the various techniques involved. It is intended principally for those people, known as DX-ers, who make the reception of short-wave broadcasts and other radio transmissions their hobby. It would not appear to have much appeal to anyone outside this specialist field.

The first four chapters deal with the propogation of short-wave signals and the methods of predicting frequencies for any particular path.

The next three chapters deal successively with source of interference, aerials and receivers.

Chapter VIII is a brief historical review of the development of the high-frequency spectrum at successive International Radio Conferences since 1927.

The last three chapters deal with DX-ing, the hobby of a class of short-wave enthusiasts who are distinct from radio amateurs in that they do not transmit. These three chapters provide useful information for a potential DX-er with references to the SINPO Code, the more common Q-Codes and other abbreviations used principally by amateurs, and the use of tape-recorders and frequency meters for extending interest in DX-ing.

The book is completed by three tables, a list of commonly used DX terms (the language of the DX-ers) in English, French and Spanish, a list of world-wide stations which transmit standard frequencies, and a list of the more important short-wave DX Clubs through the world. Unfortunately, the list of standard frequencies are quoted incorrectly in kc/s instead of Mc/s.

The book has been well translated from Dutch.

P.N.P.

"Basic Matrix Analysis and Synthesis." G. Zelinger. M.I.E.R.E., Sen. Mem. I.E.E.E. Pergamon Press, Ltd, xv+228 pp. 54 ill. 45s.

This book deals exclusively with twoports and hence almost exclusively with 2×2 matrices; indeed, the reader of the first chapter, which describes basic matrix operations, might be excused for believing that this was the only type of matrix.

Subsequent chapters of Part I deal with the properties of twoports and their description by means of different types of matrix parameters; a noticeable omission is the scattering matrix. Part II deals with impedance matching, and Part III, which is probably the most valuable part of the book, deals with the analysis of typical circuits, particularly transistor feedback amplifiers. Results for typical configurations are summarized in some useful tables.

The concentration upon twoports causes approximately equal weight to be accorded to the various types of matrix, and the special power of the admittance parameters, whereby any complex interconnexion may immediately be represented as an $n\times n$ matrix and subsequently reduced by routine methods, is not indicated. The important concept of the indefinite, or floating, matrix seems to receive insufficient emphasis.

Any book which aims at presenting the elements of a subject in a simple form suitable for a novice in the field should take pains to ensure that its statements are correct. For example, the sentence "By definition, the cofactor, or signed 'minor' of the determinant is the element, or group of elements which remain after the indicated row and column are deleted," could well cause confusion, even if, as here, it is followed by correct formulae which contradict the statement.

Any good book on the matrix analysis of circuits (it is difficult to see, nor does this book indicate, how one can synthesize by matrix methods) would form a valuable addition to the literature. This book is not without some value but does not seem to have fully exploited the opportunities open to an author in this field.

T.B.M.N.

Switching and Signalling Techniques for the Intercontinental Automatic Telex Service

Part 1—Type C Signalling

E. E. DANIELS and W. A. ELLIS, C.Eng., M.I.E.E.†

U.D.C. 621.394.34:621.394.63

Considerable progress has been made towards the establishment of an intercontinental telex transit-switching network based upon the standards adopted at the 1964 Plenary Assembly of the C.C.I.T.T. Part 1 of this article describes the new signalling system to be used for the network; Part 2 will describe the intercontinental switching equipment being provided in London, which will not only form part of this transit network but will also permit the extension of a fully-automatic telex service to all parts of the world.

INTRODUCTION

DURING the last C.C.I.T.T.* study period considerable attention was given to the problems relating to a fully-automatic intercontinental telex service, and, in particular, to the standards to be adopted in establishing an intercontinental transit-switching network. Substantial progress was achieved in this connexion by the adoption, at the 1964 Plenary Assembly, of a number of features applying to such a transit network. These included the principles to be followed in the routing, including alternative routing, of transit calls, the charging arrangements for them, the method of access to the transit network, the grade of service at which circuits will be provided, a standardized range of destination codes, and also a new signalling system designated Type C signalling.

The Type C signalling system and some of the reasons leading to its adoption form the subject of this part of the article. The second part will describe the equipment, using techniques suited to the new signalling system, now being provided in London for automatically switching intercontinental telex traffic.

ADVANTAGES OF A STANDARDIZED SIGNALLING SYSTEM

In order to obtain the maximum benefit from any standardized system, it is necessary to rigidly specify the characteristics, not only of the method of signalling, but to some extent of switching also. The advantages arising from the adoption of a suitable standard can be summarized as follows.

(*i*) The service offered to subscribers can be improved, and the ineffective time of expensive intercontinental trunk circuits on both transit and terminal calls can be reduced, by the adoption of faster call setting-up times.

(*ii*) Improved utilization of the intercontinental network is possible due to transit switching, and to automatic alternative-routing facilities if these are made available. For example, the introduction of time-division-multiplex equipment or satellite operation tends to make trunk-circuit capacity become available in large increments between certain points, and the availability of an attractive automatic transit system will enable maximum use to be made of this capacity and, at the same time, will avoid the uneconomic provision of numerous small direct routings.

(*iii*) The range of equipment to be supplied by each Administration will be simplified, and there will be no need to exchange technical information with other Administrations to permit inter-working. If and when equipment changes are made in a network, the repercussions on other networks will be considerably reduced.

(*iv*) The signalling demands on transmission systems will be a minimum, and, therefore, difficulties will be less likely to arise with any new transmission systems which are developed. The cost of providing special signalling equipment on such systems will be avoided.

(*v*) Flexibility in the use of switching equipment to meet unexpected development of particular routes, or in the event of re-routings due to circuit breakdown, will be enhanced because of the ability to signal over all types of circuits.

(*vi*) The signalling system can be designed to provide a more reliable service by giving protection against such defects as faulty transmission and dual seizure of circuits. Design points of this nature, which are embodied in the Type C system, are discussed in more detail in later sections.

LIMITATIONS OF EXISTING SIGNALLING SYSTEMS

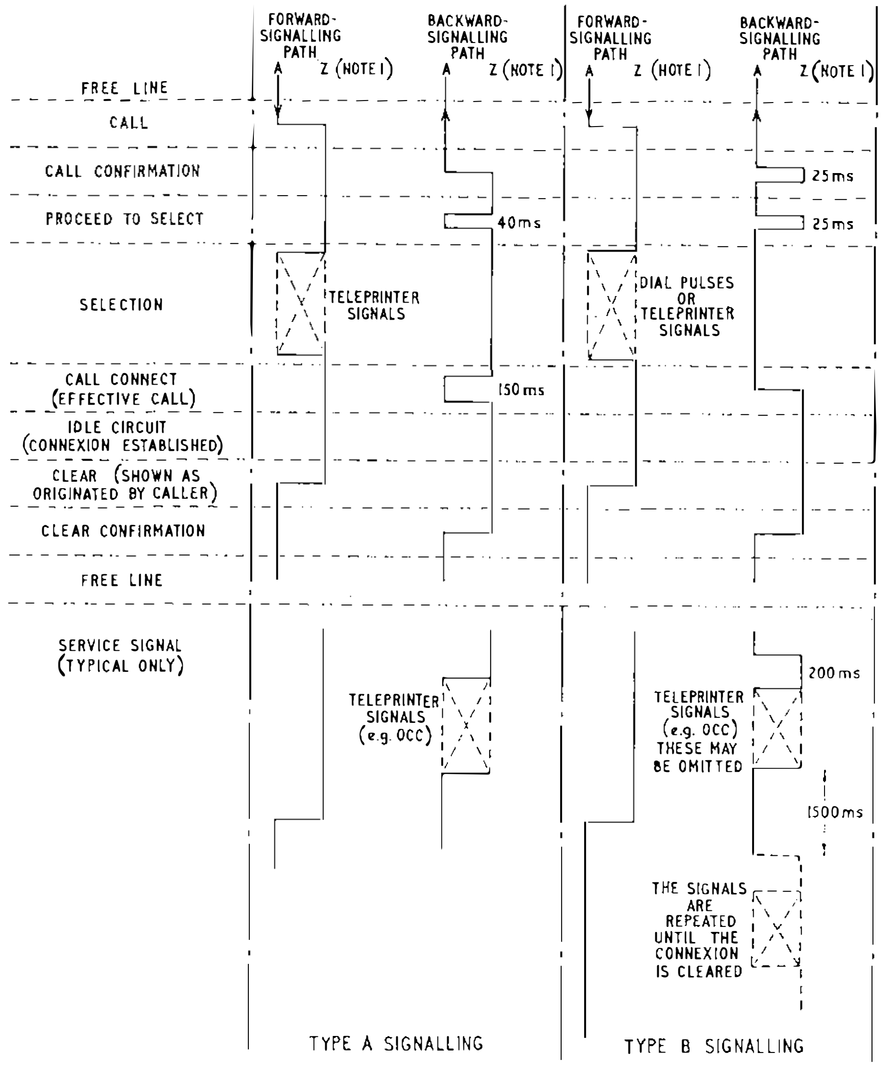
The C.C.I.T.T. recommendations for the earlier telex signalling standards on cable circuits, Type A and Type B signalling,[1,2] had been drawn up primarily to meet the conditions arising in the European network, where suitable direct circuits are relatively cheap and there is little need for transit working. These signalling standards have been largely derived from existing domestic systems, and this has given rise to a number of variants for each type according to the form of selection signals employed, whether dial or keyboard, and the signals returned to the caller on ineffective calls to indicate the reason for failure.

The existing systems, the signalling principles of which are illustrated in Fig. 1, are subject to the following limitations concerning intercontinental working.

(*i*) Both types include pulse signals which do not correspond to combinations of the International Alphabet No. 2, and, in consequence, cannot be transmitted over all types of transmission system unless these have special facilities incorporated into their design.

(*ii*) If successive links of a tandem connexion use different types of signalling it is necessary to provide comparatively complex equipment at each transit point to discriminate between the signals returned over the backward signalling path for effective and ineffective calls, and to convert these to the alternative form of signalling without losing the intelligence contained in the original signals. In any event, such conversions introduce delay in setting-up calls and are, therefore, undesirable for a long-distance transit network. If

†Telegraph and Data Systems Branch, Engineering Department.
*C.C.I.T.T.—International Telegraph and Telephone Consultative Committee.



Notes: 1. The conventions used to indicate polarities of signals are:
A = start polarity (= space polarity, + 80 volts in the United Kingdom),
Z = stop polarity (= mark polarity, − 80 volts in the United Kingdom)
(the use of A and Z to indicate start and stop polarities is internationally recognized).

2. The durations indicated for the signals are nominal.

FIG. 1—PRINCIPLES OF C.C.I.T.T. TYPE A AND TYPE B INTERNATIONAL TELEX TRUNK SIGNALLING

successive links of a tandem connexion use different forms of selection, the storage and conversion required prior to re-transmission also involve undesirable delays.

(*iii*) Both existing systems, when incorporating registers, use sequential-signalling arrangements in which a calling signal is transmitted, is acknowledged by the return of a proceed-to-select signal when a distant register is available, and the selection signals are then transmitted. Either system, therefore, tends to slow down the speed at which calls can be set up, especially over circuits incurring the long propagation delays met on many of the types of transmission system used on intercontinental routes.

(*iv*) Because of the non-coincidental peak traffic periods in the two directions encountered in intercontinental relations, bothway working is required in order to ensure that the circuits are used efficiently. Type A signalling is not well suited to bothway working, because, with identical call and call-confirmation signals, there is a liability to "lock-out" due to spurious calling signals arising from line interruptions.

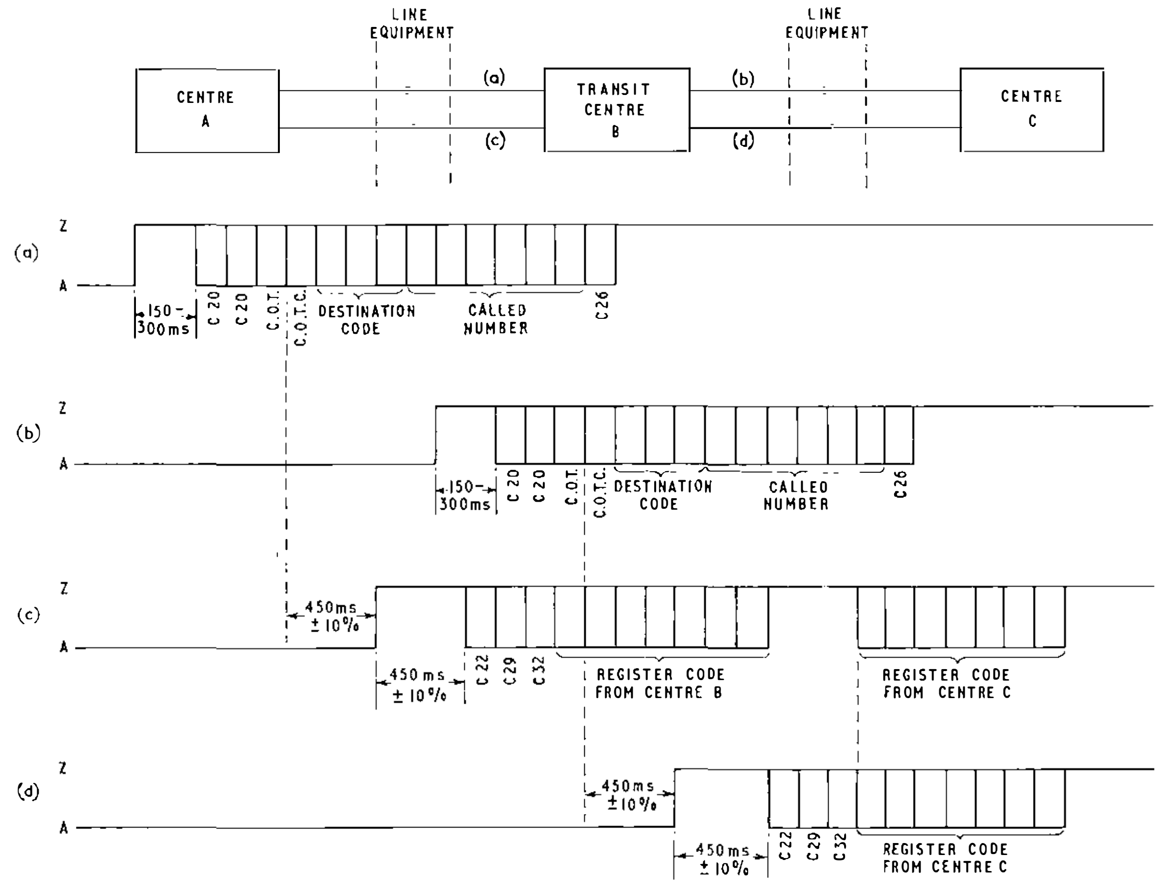
(*v*) Type B signalling does not permit the return of teleprinter signals to the calling system while the connexion is being set up.

TYPE C SIGNALLING BETWEEN TRANSIT CENTRES

Type C is a fast-signalling system based entirely on the exchange of teleprinter signals, the timing of which permits the best features of the two existing systems to be retained.

The calling and selection signals are transmitted as a single group of characters to each transit exchange in the connexion in turn, with their extension to each succeeding exchange occurring as soon as possible until the last transit exchange is reached. These signals and their associated backward-path signals are shown in Fig. 2, the individual signalling conditions being described in the following paragraphs. The additional signals appropriate to the last transit centre are described later.

In the descriptions which follow, the conventions detailed below are used.



A = start polarity. Z = stop polarity
C = combination number
C.O.T. = class-of-traffic signal
C.O.T.C. = class-of-traffic check signal

Note: No allowance has been made for switching time within the exchange or for loop propagation delay.

FIG. 2—TYPE C SIGNALS VIA A TRANSIT CENTRE DURING SELECTION STAGE

The two signalling polarities used are "start" polarity (A), corresponding to the condition applying during the start element of the teleprinter character, and "stop" polarity (Z), corresponding to that applying during the stop element. Supervisory conditions corresponding to continuous start or stop polarities are transmitted over synchronous multiplex systems as successions of α or β characters, respectively.

The "forward-signalling" path is that carrying signals transmitted by the originating system, and the "backward-signalling" path is that carrying signals transmitted by the called system when the connexion is established. Signals may, of course, be transmitted from intermediate points while the connexion is being set up.

Teleprinter characters are shown by their combination number of the International Alphabet No. 2 to avoid confusion between the two cases for letters and figures. Where they have any significance, the printed characters are also shown in brackets.

It is necessary for translation purposes to provide at all transit centres equipment capable of reading the forward-path signals as 5-unit code combinations, but this complication has been avoided on the backward-signalling path by choosing, for a number of signalling functions, combinations corresponding to single pulses of start polarity, which permit discrimination by simple timing elements. The pulse durations of these signals have been shown in brackets following the combination numbers.

The signals shown are in the form transmitted from, or received by, the switching equipment at transit centres. Over the interconnecting trunk circuits they may be converted to other forms appropriate to the transmission media.

Free-Line Signal

The free-line condition is start polarity on both forward-signalling and backward-signalling paths.

Calling Signal

The calling signal is an inversion to stop polarity for 150–300 ms followed by two combinations No. 20 (two 100 ms pulses of start polarity) on the forward path, and is followed immediately by selection signals. The lower limit of the period of stop polarity preceding the combinations No. 20 is the minimum necessary to ensure its transmission through certain types of multiplex system. The upper limit of 300 ms has been included to avoid excessive delays. However, when the calling signal is transmitted over error-corrected radio systems[3] it is desirable that the precautions against false calling signals, introduced for earlier types of signalling, should still apply. To meet this requirement the radio equipment should ensure that the period of stop polarity preceding the combinations No. 20 should be transmitted over the radio path as four consecutive β signals, and that at the incoming end the inversion to stop polarity is only extended to the switching equipment when two consecutive β signals have been received. The incoming radio equipment should also ensure that the first combination to be extended to the switching equipment is preceded by at least 140 ms of stop polarity.

The use of a non-sequential calling system with these call-signal timings means that a register must be available to accept the incoming selection signals within, say, 425 ms of the inversion to stop polarity. The increased register provision to meet this requirement is compensated by the reduced holding time of outgoing registers, and is amply justified by the faster call-setting-up times achieved. The two combinations No. 20 have no calling function, but serve to give a positive indication of dual seizure (head-on collision) if they are received instead of the correct backward-path signals on a bothway circuit. This is described in a later section. It is necessary for the incoming register to be able to absorb any combination No. 20, or any portion of one, which it may receive preceding the selection signals.

Selection Signals

The selection signals comprise a class-of-traffic combination, a class-of-traffic check combination, the two or three digits of the destination code, the required subscriber's number, and, finally, an end-of-selection signal (combination No. 26).

Class-of-Traffic Signals. Class-of-traffic signals relate the call to a particular category of traffic. Discrimination is achieved by examination of the first four code elements of the signal, the polarities of which have the following significance.

Stop polarity for the first code element indicates that the ensuing call will be transmitted at 50 bauds; start polarity is reserved for the possible use of higher modulation rates, for which separate groups of special circuits would be selected.

The polarities of the second and third elements in combination indicate the type of call: whether telex (ZZ), gentex (AZ), requiring access to service positions (ZA), or a further reserved category (AA). The last could, for example, be used for messages sent in codes other than 5-unit, which would require the selection of circuits without multiplex or other similar equipment suitable only for specific codes.

The polarity of the fourth element indicates whether or not a call has been previously alternatively routed. At present, in the absence of other precautions, alternative routing is restricted to a single occasion for any call, to preclude the possibility of the call being subsequently routed back to the originating exchange.

The fifth element of the class-of-traffic signals is always start polarity.

Class-of-Traffic Check Signals. The characters comprising class-of-traffic check signals are complementary to the class-of-traffic signals in having each of the five code elements reversed in polarity. Correct reception of the appropriate class-of-traffic check signal provides a test of the ability of the forward-signalling path to transmit 5-unit code signals, and is especially useful in the case of multiplex equipment having 5-unit storage devices, where failure may be restricted to a single element.

Destination Code and Subscriber's Number. The number of digits in the destination code and called number combined has been provisionally limited to 12.

To ensure fast switching within the transit network it has been specified that forward selection should commence immediately sufficient digits have been received to determine the onward routing of the call. This corresponds to the receipt of the initial digit of the subscriber's number, which may be required in order to discriminate when there is more than one route to the destination system, or to permit barring to certain traffic categories. It is also required that these routing digits will be re-transmitted without delay by the transit centre. From Fig. 2 it will be seen that the maximum time required to switch through a transit exchange, measured from the receipt of the calling signal on an incoming route to the offering of the calling signal on the outgoing route, lies between the limits of 1,200 ms and 1,500 ms, plus the switching time within the exchange. These limits are independent of the propagation time of the trunk circuits. To ensure an adequate speed of switching, the switching time within the exchange is limited to 800 ms maximum.

The possibility was considered of having different class-of-traffic categories for terminal and transit calls, so avoiding the need to transmit the destination code on terminal calls and, thus, reducing the setting-up time on a significant proportion of calls, but, in the interests of standardization, such an arrangement was not adopted.

Reception-Confirmation Signal

The reception-confirmation signal confirms receipt of the calling signal, and comprises inversion of the backward-signalling path for 450 ms (± 10 per cent) followed by combination No. 22 (40 ms pulse of start polarity). It is returned 450 ms (± 10 per cent) after recognition of a valid class-of-traffic character.

The combination No. 22 is not essential in view of the following signals, but is included to give an early positive discrimination between the reception-confirmation signal and any other backward-path signal. The arrangement, whereby the return of the reception-confirmation signal is dependent on receipt of the first selection signal, makes the system virtually immune from incorrect operation due to imitation by spurious signals.

Transmission-Confirmation Signal

The transmission-confirmation signal comprises combination No. 29 (20 ms pulse of start polarity) and combination No. 32 (120 ms pulse of start polarity). It is transmitted immediately following the reception-confirmation signal, subject to the class-of-traffic check of the forward path being satisfactory. Again, this pair of signals is complementary, and provides a rudimentary transmission check of the backward path similar to that provided on the forward path by the class-of-traffic and class-of-traffic check signals.

Up to this point the backward-path signals are absorbed by the previous exchange and are not allowed to be received by any preceding centre.

Register-Code Signals

The register-code signals are a group of seven characters: combination No. 31 (space), combination No. 29 (letter-shift), two letters identifying the transit centre, combination No. 30 (figure-shift), and two figures

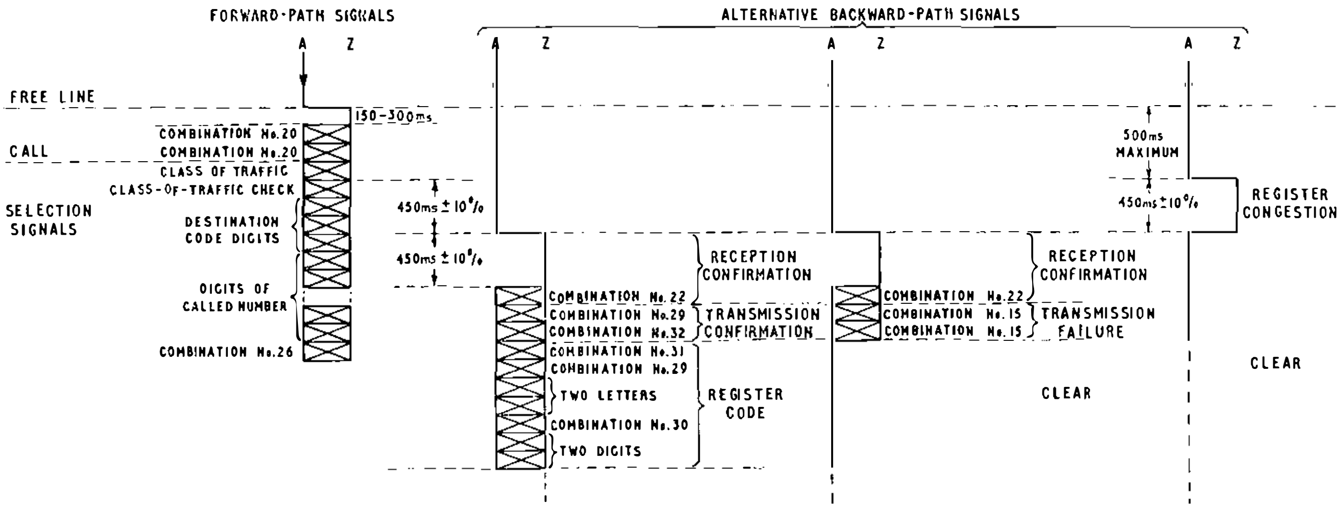


FIG. 3—TYPE C SIGNALLING: ALTERNATIVE BACKWARD-PATH SIGNALS

identifying the register used for the call.

For telex traffic the C.C.I.T.T. has made the originating administration responsible for all international-accounting arrangements, limiting the responsibility of a transit centre to merely switching the connexion. The register codes which pass through all intermediate transit centres provide the originating system with the necessary information for apportioning transit charges.

The timings of the signals, illustrated in Fig. 2, have been chosen to prevent register codes overlapping in the event of all factors being adverse, including zero switching delay.

Alternative Backward-Path Signals

The alternative backward-path signals, shown in Fig. 3, include the following.

Transmission-Failure Signal. In the event of the class-of-traffic check of the forward-path signals not being successful, a pair of non-complementary characters, two combinations No. 15 (two 80 ms pulses of start polarity), are returned instead of the transmission-confirmation signal to the preceding exchange. On receipt of this signal, or, if for any other reason the reception-confirmation and transmission-confirmation signals are not received correctly in the preceding transit exchange, a service signal containing the printing characters NC (no circuits) is returned to the calling exchange following the register code to indicate transit failure, and the outgoing trunk circuit is then automatically retested.

In addition to being returned as indicated above, the transit-failure signal is also returned if all available outgoing circuits are busy, if the first three digits following the class-of-traffic check signal do not conform to a valid code, or if the incoming selection signals following the class-of-traffic signal are delayed for more than 5 seconds. In those cases which do not correspond to a faulty outgoing trunk circuit the automatic retest is not initiated.

Register-Congestion Signal. In the absence of a proceed-to-select signal it is necessary to introduce a separate signal to indicate register congestion, but the use of this signal has the advantage that, when congestion occurs at an incoming-register stage, it prevents any appreciable increase in the holding time of the outgoing registers in the other exchanges and so avoids the tendency to spread congestion. The register-congestion signal comprises inversion of the backward-signalling path to stop polarity for 450 ms (± 10 per cent) followed by reversion to continuous start polarity. It should be transmitted within 500 ms of the commencement of the calling signal.

The register-congestion signal should not be returned on more than 0·4 per cent of calls in the busy hour, and the equipment should ensure that the signal is returned only when register congestion is positively identified and not for a fault in the register-access equipment. Again, on receipt of the register-congestion signal, the transit-failure signal is returned to terminate the call attempt.

Dual Seizure (*Head-On Collision*). Although steps may be taken to reduce the incidence of dual seizure, such as offering the traffic to the trunks in inverse order at each end and providing full-availability access to large groups of circuits, its occurrence can still cause a significant deterioration in the grade of service if the calls are allowed to fail, especially if routes are operated on a high-usage basis with automatic overflow or in the event of the busy-hour traffic stream in the two directions being unequal. The latter case is likely to be prevalent on intercontinental trunks, where the terminal networks generally have non-coincidental peak-traffic periods.

A dual seizure is detected when the calling end receives combination No. 20 (100 ms pulse of start polarity) instead of combination No. 22 (40 ms pulse of start polarity) and is confirmed by receipt of a second combination No. 20. Both calling registers release the trunk and offer the call to the same route a second time after a delay of 2·5 seconds, which allows time for the guard delay on the circuit to have expired. It was earlier intended that the centre with the smaller ratio of outgoing to incoming calls should be given priority of recall, as the loss due to dual seizure is more significant in this direction. The end with priority would re-offer the call to the same route after expiration of the guard delay, an arrangement which offers the greatest possibility of a successful recall, and the end without priority would overflow the call immediately, if an alternative route existed, or else return the NC signal. However, this arrangement was considered by the C.C.I.T.T. to be too complicated, and the simpler method has been adopted.

In the event of a second dual seizure, either on the direct route or on overflow to an alternative route, the NC signal is returned and no further attempts are made to recall.

If the second combination No. 20 is not received within 2 seconds, the circuit is assumed to be faulty, the transit-failure signal is returned, and a retest is applied.

SIGNAL CONVERSION AT THE LAST TRANSIT CENTRE

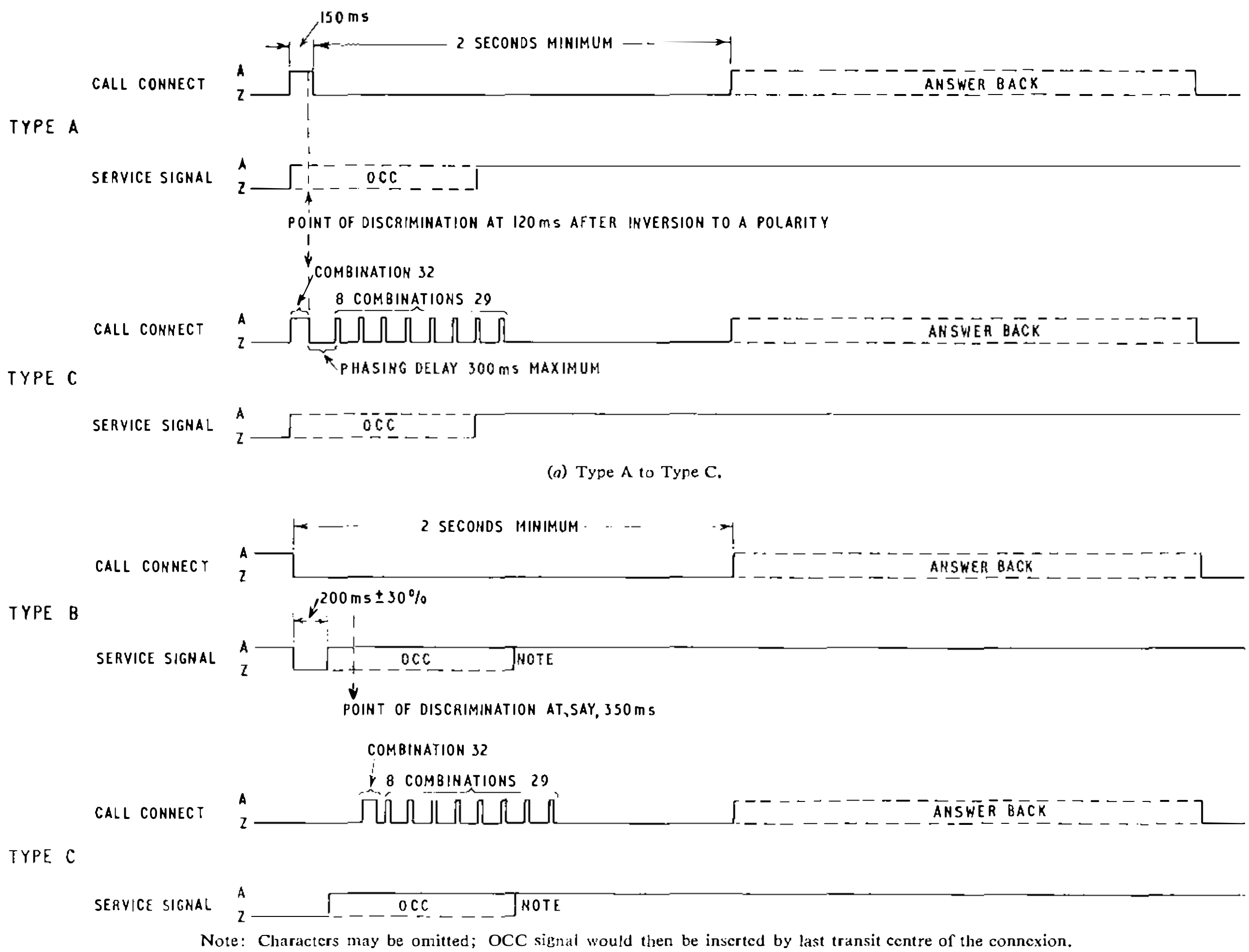
The type of signalling to be used between the last transit centre in a connexion and the terminal country has been left to bilateral agreement between the countries concerned, but in most relations the last transit centre must be capable of completing the connexion using either Type A or Type B signalling, or the variant of Type A adapted for operation over error-corrected radio circuits. Conversion will be required on the backward-signalling path for the Type A and Type B call-connected signals and Type B service signals when these are of the non-printing variety.

Call-Connected Signal

The Type A and Type B call-connected signals include a minimum period of 2 seconds stop polarity, primarily to permit the calling teleprinter motor to reach governed speed, prior to characters being received, in those systems which delay starting the teleprinter motor until a call is established. As the transit network may include error-corrected radio links, over which the stop-polarity signals could be eliminated during cycling, it is necessary to replace the Type A and Type B call-connected signal by a succession of distinctive non-printing teleprinter signals: the succession of signals chosen is combination No. 32 followed by eight combinations No. 29.

On calls to those countries from which the called-subscriber's answer-back is not returned automatically, it is required that this should be obtained by the last transit centre following transmission of the characters of the call-connected signal.

With the connexion established the idle-circuit condition is stop polarity on both signalling paths.



Note: Characters may be omitted; OCC signal would then be inserted by last transit centre of the connexion.

(*a*) Type A to Type C.

(*b*) Type B to Type C

FIG. 4—CALL-CONNECT/SERVICE SIGNAL DISCRIMINATION AND CONVERSION TO TYPE C SIGNALS

Service Signals

When printing service signals are returned by the Type A or Type B system these are merely passed unchanged through the transit network. With Type B non-printing signals, however, conversion is necessary, the busy pulse being re-transmitted as the OCC (occupé) signal, and the two other fault conditions of permanent start polarity or permanent stop polarity (failure of called-subscriber answer-back) being re-transmitted as the DER (dérangé) signal. A limit to the delay in returning the DER signal is specified, to avoid holding trunk circuits unnecessarily.

Fig. 4(*a*) and (*b*) show the discrimination required between call-connected and service signals in the case of Type A and Type B signalling, respectively, and the conversion necessary for the call-connected signal.

With Type A signalling the call-connected signal comprises a 150 ms pulse of start polarity followed by stop polarity for a minimum of 2 seconds and then teleprinter signals. A service signal comprises a group of teleprinter signals, in which the periods of start polarity have a maximum of 100 ms, followed by a clearing signal. If, therefore, a pulse of start polarity is received which persists for 120 ms the backward path is then switched to stop polarity to form the initial combination No. 32 of the Type C call-connected signal. Next, the eight combinations No. 29 are inserted, and then the backward path is reconnected to allow the following teleprinter signals to be received by the caller. If the pulses of start polarity are less than 120 ms, the backward path is left through and the signals received from the terminal country are allowed to pass unchanged.

For Type B signalling, reversion from stop to start polarity prior to the instant of discrimination indicates a service signal, and the backward path is merely left connected through. In the absence of such an inversion the combination No. 32 and combinations No. 29 are signalled, and the backward path is reconnected to allow the answer-back to follow.

MISCELLANEOUS SIGNALS

Clear Signal

The clear signal is inversion to continuous start polarity on either signal path. The minimum recognition time for the signal is 300 ms.

Clear-Confirmation Signal

The clear-confirmation signal is inversion to start polarity in the opposite direction to clearing, within 500 ms ($\pm$20 per cent) of the start of the clear signal. The guarding arrangements are such that the trunk circuit equipment must be available to accept a new call within 1 second of the start of the clear-confirmation signal. As a tolerance on this delay, a new call should not be offered in less than 1·5 seconds. For error-corrected radio trunk circuits the guard delay will commence following the exchange of α signals, as stipulated for the existing signalling system.

Backward-Busy Signal

For busying the distant end of bothway or incoming circuits for maintenance purposes a backward-busy signal of continuous stop polarity is specified. A maximum duration of 5 minutes has been placed on this signal to avoid the unnecessary operation of alarms in the distant centre.

Automatic-Reset Signal

When a trunk circuit is found to be faulty a service signal is returned to the caller, and the trunk is then retested periodically to permit its early restoration to service if the fault proves to be of a transitory nature. The automatic-retest signal is made up as follows:

300 ms stop polarity.
Combination No. 20.
Combination No. 20.
Combination No. 21 (class-of-traffic signal).
Combination No. 15 (class-of-traffic check signal).
Combination No. 16 }
Combination No. 16 } (retest destination code).
Combination No. 16 }
Stop polarity for 2 seconds.
Start polarity for either 30 or 36 seconds.

A faulty trunk is retested a maximum of five times. If on any retest a satisfactory transmission-confirmation signal is received the trunk is restored to service; if not, it is busied to outgoing traffic and an alarm is given, but incoming traffic is still permitted. In order that simultaneous retest from both ends of a bothway circuit should not cause failure, the retest cycle is repeated at different intervals (30 or 36 seconds) at the two ends.

SIGNALLING BETWEEN THE CALLING SYSTEM AND THE FIRST TRANSIT EXCHANGE

The type of signalling to apply over the link to the first transit exchange is also left to bilateral agreement. It may be in Type C format, or complete conversion from one of the existing systems may be provided at the first transit centre. It will probably be convenient in many relations, however, to compromise between these extremes and make use for transit traffic of a route which already employs either Type A or Type B signalling for fully-automatic terminal traffic. To meet this case, code OO has been standardized for access from an incoming international exchange to the intercontinental transit network. In many instances semi-automatic operation is expected to apply to transit traffic using this code, at least during an introductory period, and, for guidance, the C.C.I.T.T. has recommended a modified version of Type C signalling especially suited to this method of working.

On selecting the code OO, a transit proceed-to-select signal of at least 450 ms stop polarity followed by combination No. 22 (V or =) is received, and the number then selected. To facilitate monitoring the selection signals on the calling-operator's teleprinter, and also to conform to standard operating procedure, the special pre-signal combination No. 30 (figure-shift) is sent. With the method of operation using the pre-signal, the class-of-traffic check signal and its associated backward-path signals are omitted as being an unnecessary complication. However, when the call is extended over the intercontinental network, the full range of Type C signals is utilized beyond the first transit centre.

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(*To be continued*)

Dual-Frequency-Band Horn-Aerial Systems

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The article contains a general description of horn-aerial systems using circular-waveguide feeders, band-branching units and transducers suitable for the simultaneous transmission of orthogonally-polarized signals in the 4 and 6 GHz bands. General electrical requirements are discussed together with details of the alignment and performance of the overall aerial system and its components.

INTRODUCTION

IN 1960 it was decided to introduce into the inland-radio trunk network horn-aerial systems capable of carrying more than one band of microwave frequencies. Today these aerials are a familiar sight in many parts of the United Kingdom, and the first fully-loaded route, operating in the 4 and 6 GHz bands, is being taken into service between the Post Office Tower, London, and Bagshot radio stations, carrying the London–Bristol and London–Southampton microwave systems. This article is intended to provide some background information on the specification, design, alignment and performance of this type of aerial system.

Horn aerials were first used on microwave trunk systems by Bell Telephones in 1958; the aerial and band-branching units were operated initially in the 4 GHz band on orthogonal polarizations, but were designed for simultaneous use in the 4, 6, and 11 GHz bands.[1,2] At that time the British Post Office was considering the problems of expanding the United Kingdom microwave system from a number of isolated links into an integrated network, and, by comparison with other types of aerial then commercially available, the horn aerial appeared to have a number of advantages, the most significant being as follows.

(*a*) The method of launching signals in the horn aerial leads to a low reflection coefficient over a very wide frequency range, and, hence, to the aerial's suitability to carry f.m. systems of 1,800-channel capacity in the 4 and 6 GHz frequency bands.

(*b*) Because of the reduced total wind loading involved, cheaper aerial-support structures result from the use of four dual-band horn aerials in place of eight single-band aerials per hop to carry the 14 bothway broadband channels in the 4 and 6 GHz bands.

(*c*) The method of launching from within a contained structure results in a highly-directional radiation pattern with minimum radiated energy in unwanted directions, resulting in low crosstalk interference both within and between microwave routes.

The general configuration of the horn aerial is shown in Fig. 1, from which it will be seen that the reflecting surface is a truncated segment of a complete paraboloid of focal length *a*. The same optical principles will apply to the segment as to the complete paraboloid, i.e. a spherical wave launched from a virtual point source at the focus F will produce a planar wavefront across the aerial aperture. The main reason for the low reflection coefficient of the horn aerial is apparent from the diagram, since the wave front launched from the focus is turned through 90°

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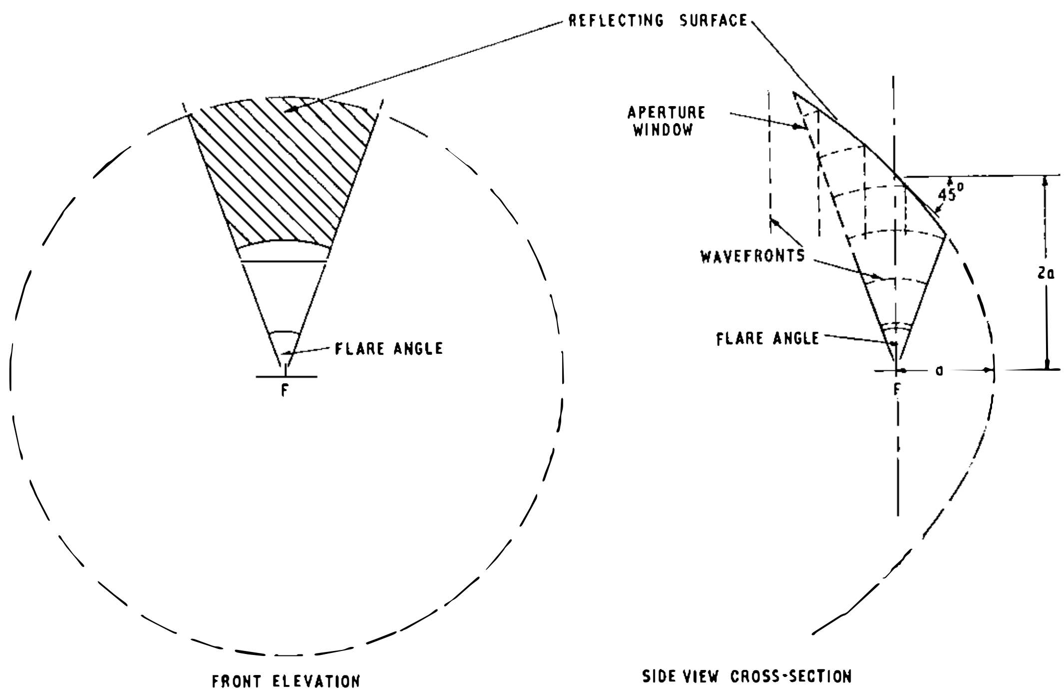


FIG. 1—HORN-AERIAL CONFIGURATION

at the reflector, thus minimizing any reflection passing back towards the focus, which would effect the impedance match at that point. A further reason is that the lower level of reflection towards the focus in the horn aerial, due to the random imperfections of the reflecting surface, is further attenuated by the much greater path loss involved, since the distance between focus and reflector surface is much greater in the case of the horn aerial than in the equivalent-aperture paraboloid aerial.

Before giving detailed descriptions of the aerials, feeders and band-branching units, it is relevant to consider the general assembly of a horn-aerial system, its application and the general electrical requirements of such a dual-band system.

GENERAL DESCRIPTION OF THE AERIAL SYSTEM

The general arrangement of a horn-antenna system is shown in Fig. 2, together with cross-sections at appropriate points in the vertical-feeder run.

Propagation in the system is by the dominant modes, which are the H_{10} mode in rectangular and square-section feeders and the H_{11} mode in circular feeders. The cross-sections given in Fig. 2 show the field configurations applicable to horizontally-polarized signals. Vertically-polarized signals will have similar but orthogonal fields.

The horn is of pyramidal form, i.e. its horizontal cross-section below the reflector is square. The lower section of the horn is terminated in a tapered transition section, forming the launching unit from the circular feeder and matching the latter to the flare angle of the horn. The aerial aperture is closed by an air-tight Terylene window.

A short flexible circular feeder below the horn facilitates the fine positional adjustment of the aerial, without causing mechanical distortion of the feeder, and also prevents vibration from the aerial passing down the main feeder. The next short section of circular feeder (the slip link) has special flanges which allow any torque between the flexible section and the main feeder, caused during aerial panning, to be released. The main mounting assembly below this bears the whole weight of the main feeder and band-branching units, other supports down the main feeder acting merely as guides and permitting vertical contraction and expansion.

The main feeder consists of a number of flange-connected circular-waveguide sections, and terminates in a circular-to-square-section tapered transition which matches the circular waveguide to the square-section band-branching unit. Lines of parallel slots, cut along the length of one wall of each of the two band-branching units, act as directional couplers of the vertically-polarized and horizontally-polarized 4 GHz fields into the appropriate separate rectangular feeders. The 6 GHz signals pass through the band-branching units to a tapered square-to-circular-section transition, which has a cut-off frequency above the 4 GHz band. These vertically-polarized and horizontally-polarized signals are coupled out of the small-section circular guide into two separate rectangular waveguides by means of the two orthogonal transducers. The vertical feeder is terminated in a waveguide load-section, which absorbs any residual 6 GHz uncoupled signals. The aerial system is reciprocal, and any rectangular port may be used to transmit or receive signals.

The whole system is pressurized (at about 5 in. water-gauge) with circulating dried air, and all joints are made

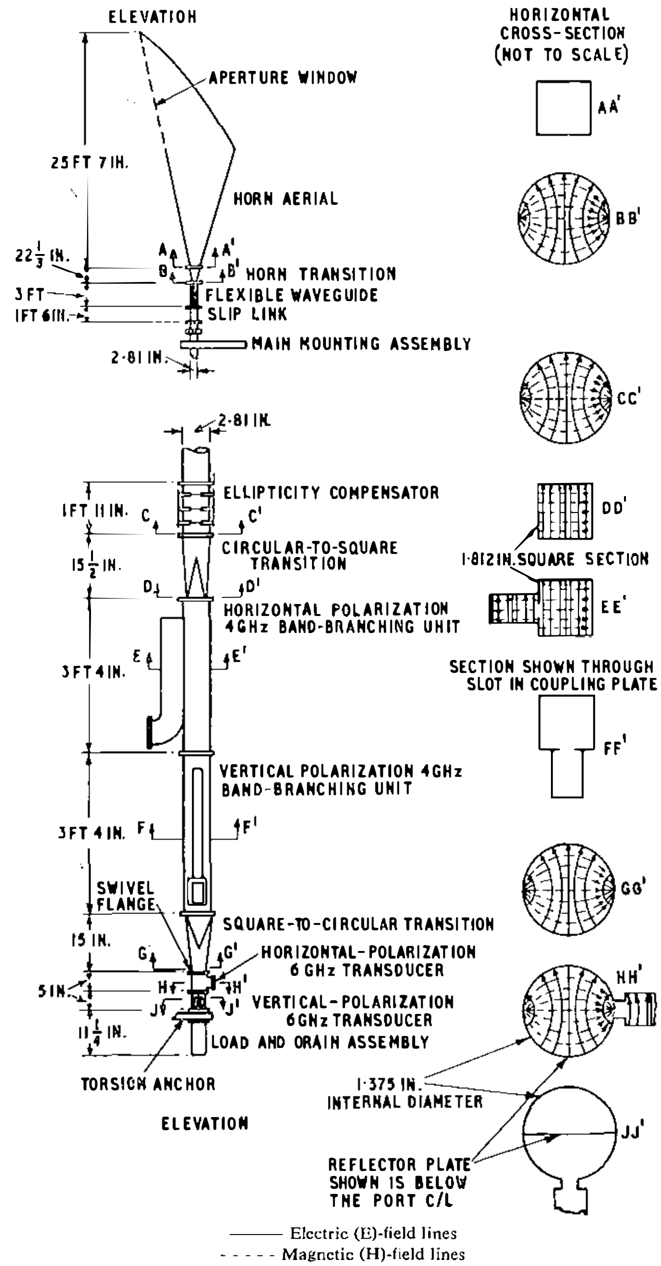


FIG. 2—HORN AERIAL, CIRCULAR WAVEGUIDE AND BAND-BRANCHING ASSEMBLY

air-tight by using sealing gaskets backed up by polyurethane paint overall.

As already implied, one horn aerial will support half the total channels in the 4 and 6 GHz bands. On a low-growth route, two horn aerials per hop are installed initially, and are operated bi-directionally with the alternate assigned transmit frequencies of each band on one polarization and the alternate receive frequencies on the other. For a high-growth route, four horn aerials per hop are installed, and uni-directional aerial operation is preferred with adjacent transmit (or receive) frequencies of each band on different polarizations of the same aerial. Fig. 3 gives the 4 GHz band frequency plan, and Fig. 4 shows diagrammatically the two methods of route development in that band; the 6 GHz band follows

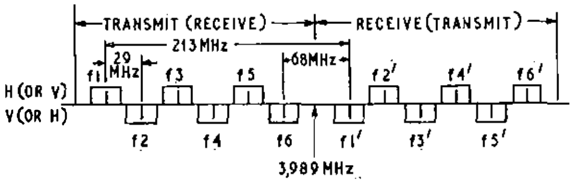
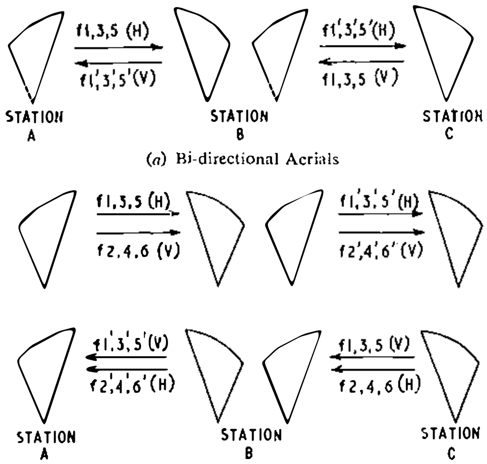


FIG. 3—FREQUENCY ARRANGEMENTS FOR 4 GHz BAND

similar patterns except that it has eight instead of six carrier frequencies in each direction of transmission.[3] The general performance of the aerial system must cater for either method of route development.



(a) Bi-directional Aerials

(b) Unidirectional Aerials

FIG. 4—TWO METHODS OF ROUTE DEVELOPMENT IN 4 GHz BAND

GENERAL ELECTRICAL REQUIREMENTS

System Gain

The free-space transmission loss between microwave aerials, each having an aperture A, is proportional to $[1/Af]^2$, where f is the frequency. It follows that the choice of aerial aperture for dual-frequency-band operation will be determined by the requirements in the lower frequency band, presuming the aerial to have the same nominal illumination efficiency in the two bands and that the same transmitter powers and receiver noise factors apply in both bands.

An aerial gain of the order of 42 dB at 4 GHz is required, in order that the overall free-space loss between repeater stations shall not exceed about 65 dB for the longest planned microwave hops of about 35 miles.

Polar Characteristics

The aerial polar characteristics will determine the go-to-return crosstalk within a given microwave route and also any crosstalk between crossing routes. For this reason the general limits of the horizontal polar diagram are specified; in particular, the ratio between forward and backward radiation gain of the aerial (or "back-to-front" ratio as it is termed) is required to exceed 65 dB.

The cross-polar characteristics between about 60° and 90° with the main beam are important, since, at a radio station where two microwave routes cross, the same transmitter frequencies will be used but on different polarizations on the two routes. Crossing-route arrangements are shown schematically in Fig. 5; an inadequate cross-polar characteristic will result in crosstalk between

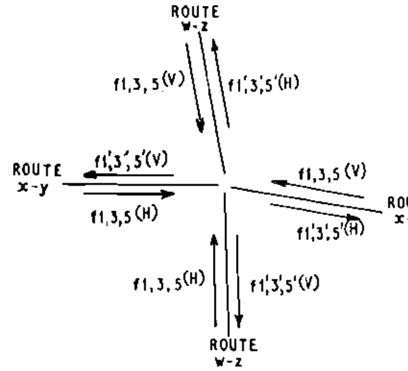


FIG. 5—CHANNEL ARRANGEMENTS AT A CROSSING-ROUTE STATION

the two routes.

These required characteristics, including the back-to-front ratio, are more readily achieved with horn than with paraboloid aerials; the latter use small launching horns with feeders and supports placed in the aperture, and from these scattering tends to take place in undesired directions, particularly towards the paraboloid edge from which diffraction can occur in a backward direction.

Cross-Polar Discrimination

The cross-polar discrimination of the system may be defined as the ratio of the wanted signal level at its input/output port to its cross-polar component at the orthogonally-polarized input/output port in the same frequency band. Low cross-polar discrimination is most likely to cause interference[4] on a uni-directional aerial between adjacent receiving broadband channels which are differently polarized. The spacing between adjacent broadband channels is of the order of 29 MHz, and the f.m. spectrum required for 1,800-channel telephony loading is about ± 12 MHz relative to the carrier. Since the wanted spectrum must have highly-linear amplitude and phase characteristics, it is difficult to obtain a very sharp cut-off in the receive-filter characteristic to discriminate against adjacent orthogonally-polarized carriers and their sidebands, which must be adequately attenuated in the wanted receive channel prior to any non-linear/limiting section of the receiver. To provide this discrimination a cross-polar discrimination of 28 dB is specified for each hop across the whole frequency range of each band and in either plane of polarization. This cross-polar discrimination is, in effect, the sum of the cross-polar components due to the aerials and to the cross-polar distortion in both the circular feeders and band-branching units at any one frequency.

Impedance Matching

It is important that a good impedance match should be maintained over the whole frequency band in all components interconnected by long lengths of vertical or horizontal waveguide feeders, in order to minimize the amplitude of long-delay echoes and the resultant intermodulation distortion.[5] The amplitude of these echoes is directly proportional to the product of the reflection coefficients of a pair of such mis-matches and twice the attenuation ratio of the interconnecting feeder. For example, a 0·06 per cent echo in a feeder longer than 100 ft can result in a maximum of 5 pW weighted intermodulation noise in a 3·1 kHz test slot of an 1,800-channel telephony system.

Intermodulation Noise

In addition to the echo effects of the wanted modes described above, it is possible that mode conversion from the dominant to a higher order mode may take place in the aerial system. Such over-moded signals will be reflected at the first section in the feeder run which is beyond the cut-off frequency for the particular mode and will be partly reconverted to the dominant mode in the aerial. Thus, intermodulation distortion may result from echoes due to mode conversion, which may not be detectable by dominant-mode match measurements at the rectangular ports.

The total intermodulation-distortion contribution due to all sources in a single aerial system is, therefore, specified: it is required not to exceed 8 pW of weighted noise in any 3·1 kHz telephony channel at baseband.

Amplitude Non-linearity

In a bi-directional aerial system the 4 and 6 GHz frequency plans ensure that the receive channel frequencies most liable to interference from any third-order products of transmitter frequencies caused by aerial-system non-linearity are carried on different aerials from the potentially interfering transmitters. Under emergency conditions, however, when one aerial has to be taken out of service, internal waveguide re-arrangements can be made so that the remaining aerial will carry all the traffic channels. Some impairment of performance will occur, particularly between the closest-spaced transmit and receive frequencies at the centre of the band, and, in addition, the possibility of interference due to third-order products will be enhanced.

A high degree of linearity in the overall aerial and feeder ystem is, therefore, required so that the level of third-order products of transmitter frequencies does not exceed −120 dBW, or 1 picowatt, at the appropriate rectangular ports.

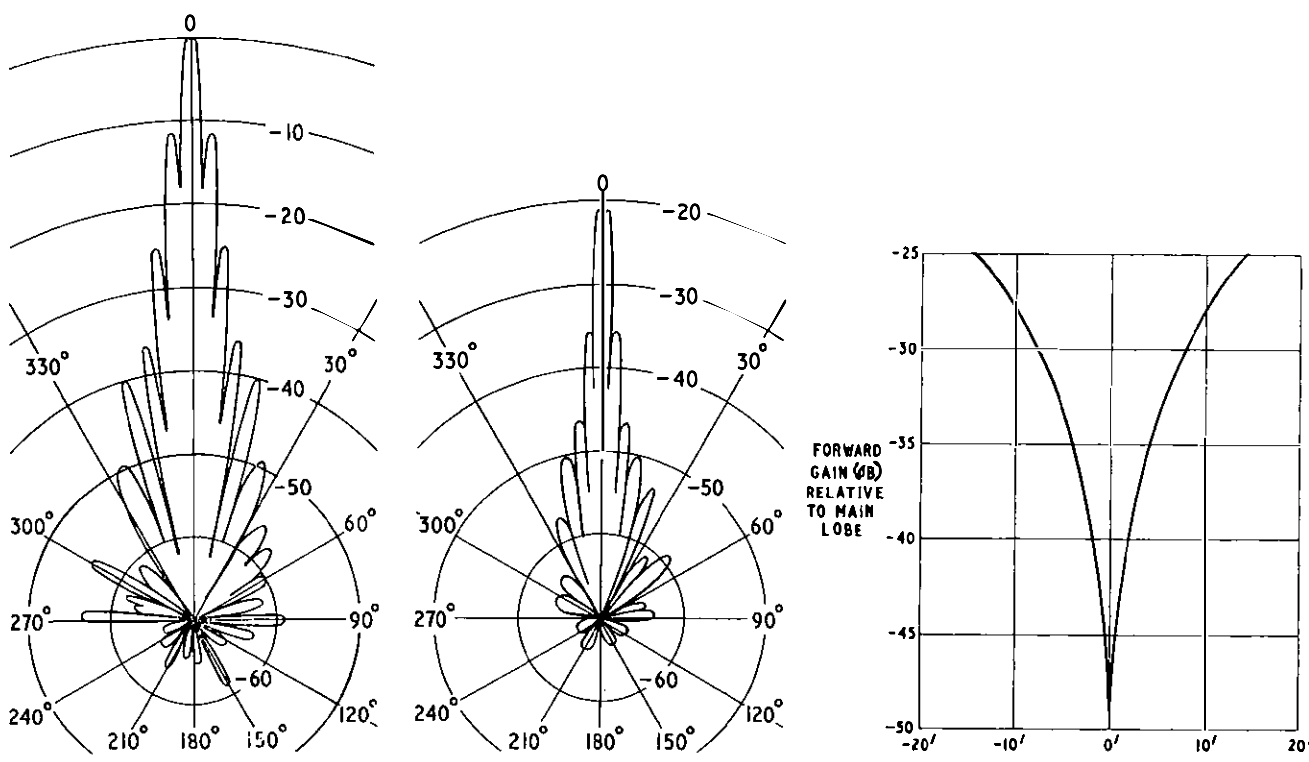
DESIGN AND PERFORMANCE OF AERIAL-SYSTEM COMPONENTS

Horn Aerial

Two sizes of horn aerial are used to give flexibility in planning microwave routes of varying lengths and tower heights, and some of their mechanical and electrical properties are summarized in the table. The aerials are constructed from braced aluminium-alloy sheet, and the reflection surface of the larger horn is formed by metallizing sprayed on to a preformed asbestos surface. The same horn-flare transition is used for both sizes of aerial, and this and the two other transitions in the main feeder

Horn-Aerial Mechanical and Electrical Properties

Mechanical or Electrical Property	Type A Horn Aerial	Type B Horn Aerial
Aperture	60 ft²	123 ft²
Focal length	5 ft 1 in.	10 ft 4 in.
Flare angle	40°	30°
Total weight	570 lb	2,835 lb
Tolerance of reflector surface (reference true paraboloid)	± 0·080 in.	± 0·080 in.
3 dB beam width at 6·175 GHz	1·4°	1·0°
Gain at 6·175 GHz	41·5 dB	45 dB
Efficiency at 6·175 GHz	47·4 per cent	52 per cent
3 dB beam width at 4 GHz	2·2°	1·4°
Gain at 4 GHz	38 dB	41·5 dB
Efficiency at 4 GHz	50·5 per cent	55·2 per cent



(*a*) Polar (*b*) Cross-Polar (*c*) Cross-Polar Cusp

FIG. 6—HORIZONTALLY-POLARIZED RADIATION CHARACTERISTICS AT 6,200 MHz IN A HORIZONTAL PLANE

run are made by the electro-deposition of copper (0·1 in. thick) on to shaped mandrels. The transition profiles are chosen to give a gradual transformation from H_{11} to H_{10} modes or vice versa, and, hence, minimal reflection effects.

The slight difference in efficiency (the ratio of effective-to-actual aperture) of the aerials between the 4 and 6 GHz bands is due both to profile variations causing a greater reduction in gain at shorter wavelengths,[6] and to the reduced illumination at the edges of the reflector which is only partly offset by the higher gain of the launcher at 6 GHz.

The polar and cross-polar radiation characteristics of the larger horn aerial at 6·2 GHz are shown in Fig. 6, in dB with reference to the forward gain of the aerial. It will be noticed that the width of the cross-polar cusp on beam is very narrow, being narrower than that of an equivalent-aperture paraboloid aerial. This effect arises mainly from the fact that a circular paraboloid aerial has two orthogonal axes of symmetry but the horn-aerial reflecting surface is only symmetrical about a vertical axis. Thus, for very small angular movements about a vertical axis, the cross-polar components due to each quarter of a paraboloid aerial tend to cancel as a pair on each side of the vertical axis, but under the same conditions any cancellation effect is much reduced in a horn aerial, resulting in the cross-polar level rising more steeply from the null at the centre of the beam.

Circular Waveguide

The circular waveguide[7] of drawn copper is manufactured in 15 ft lengths having an internal diameter of 2·812 ± 0·002 in. The effective major and minor axes of each waveguide length are determined electrically, and feeder runs are assembled, connecting major to minor axes to effect minimum cross-polar distortion overall. On the bottom feeder length a 3-section cramp or ellipticity compensator is fitted, enabling the best compromise cross-polar distortion across the frequency band to be achieved.

The reflection coefficient of each waveguide section is 0·001 or better, and the attenuation per 100 ft is 0·6 dB at 4 GHz, and 0·5 dB at 6 GHz.

Band-Branching Units

The square-section dimension of the band-branching units is selected to minimize higher-order mode couplings at 4 and 6 GHz, by ensuring that the cut-off frequencies of these modes fall outside the wanted bands. The two 4 GHz band-branching units are internally-machined aluminium castings with external web reinforcement; the squareness of the internal cross-section, including the 0·062 in. brass coupling plate which closes the square and rectangular guides, must be maintained along its whole length, as any variation will introduce unwanted cross-polar components in both frequency bands.

As shown in Fig. 2 (section FF′), the coupling slots are cut in the narrow face of the rectangular guide, thus coupling the two guides via the electric field across the gap. The number and position of the slots, which are symmetrically displaced about the coupling-plate centre line, are a compromise choice to effect maximum coupling across the 4 GHz band, and minimum cross-polar distortion of 6 GHz signals.

The required attenuation of 6 GHz signals coupled into the 4 GHz rectangular feeders is 65 dB; this figure is achieved by fitting wires in the plane of each coupling slot, forming ¼-wave resonant stubs at 6 GHz, and waveguide low-pass filters which also match the impedance of the band-branching unit rectangular port to the No. 11A waveguide horizontal feeder. The stub-end of each 4 GHz rectangular feeder contains a load to absorb 4 GHz residual signals not coupled in the desired direction.

6 GHz Transducers

Each of the two transducers consist of a short length of circular brass waveguide, having a thin slot cut longitudinally in the waveguide wall and a laminar plate set across one diameter of the waveguide at right angles to, and slightly below, the centre of the slot (Fig. 2 section JJ′).

Signals entering the guide via electric-field coupling from the resonant slot would travel in both directions along the circular feeder but for the presence of the laminar plate, which acts as a ¼-wave reflector, and, thus, almost all the energy coupled from the slot travels toward the aerial. The transmitted electric field of the second transducer, which is set below and orthogonal to the first, is at right angles to the plate of the first transducer and, thus, passes through it uncoupled toward the aerial.

Both slots are connected to No. 13 waveguide horizontal feeders by impedance-matching and flexible-waveguide sections. Cross-polar coupling between the two 6 GHz ports of the assembled units is better than 45 dB, and the peak reflection coefficient at either rectangular port is better than 0·03 over the frequency band.

Performance of Assembled Band-Branching Units and Transducers

The whole assembly, including the two transitions, is factory tested, using sweep-frequency methods over each appropriate frequency band, to meet the following requirements with all unused ports correctly terminated. The cross-polar discrimination of the assembly must exceed 33 dB both at 4 and 6 GHz. The insertion loss of the assembly to wanted signals must not exceed 1·0 dB in the 4 GHz band, and 0·7 dB in the 6 GHz band. The loss between any pair of ports, circular or rectangular, in the frequency range 7·4–12·85 GHz (i.e. including the second harmonics of all working frequencies) must exceed 30 dB.

OVERALL SYSTEM ALIGNMENT

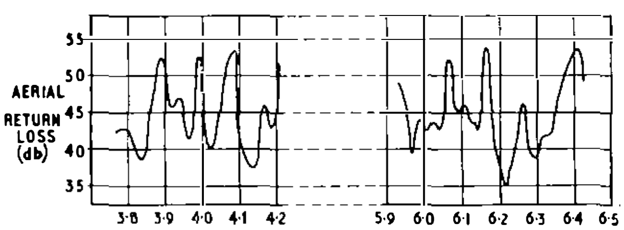
The objective in the lengthy field alignment process is to obtain an overall cross-polar discrimination of 28 dB between rectangular ports over each frequency band and in both planes of polarization. The alignment is carried out in stages, testing over each hop (*a*) between aerials only (target 35–38 dB), adjusting aerial bearing and elevation, (*b*) with signals extended down one and then both vertical feeders (target 31–33 dB), adjusting each compensator in turn, and (*c*) with signals extended to one and then the other band-branching unit assembly (overall target 28 dB), adjusting the angular orientation of, first, the band-branching unit and, then, the 6 GHz transducer. At each stage the required cross-polar discrimination must be checked and achieved across both frequency bands (since phase cancellation of distortion can occur at a single frequency), although initial alignment of stage (*a*) is made in the 6 GHz band when the aerial characteristic is narrowest (±4 minutes of arc, approximately, for the cross-polar values required), and of stage (*b*) is made in the 4 GHz band, since the eccentricity compensators have most effect at the longer wavelengths.

In order to isolate the aerials in stage (*a*), the flexible feeder below each aerial is replaced by a circular-to-rectangular test transducer which is optically aligned very carefully with the aerial and connected to the aerial by a dowelled plate. The cross-polar discrimination of the test transducer alone is better than 45 dB, thus permitting measurements of the required sensitivity. The dowelled plates are locked in position, and permit the transducers at either end of the hop to be rotated by an exact 90°, and 4 and 6 GHz versions of the transducer to be interchanged, in the course of changing polarization or frequency band during measurements, without further re-setting. The transducers are also used to terminate the extended vertical feeder in stage (*b*).

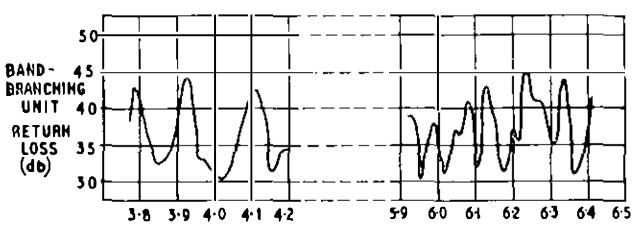
As alignment proceeds through subsequent stages, only one additional component (e.g. feeder, band-branching-unit assembly, etc.) is added at a time, thus ensuring that the previous reference plane of polarization is maintained by the unchanged aerial.

OVERALL FIELD PERFORMANCE

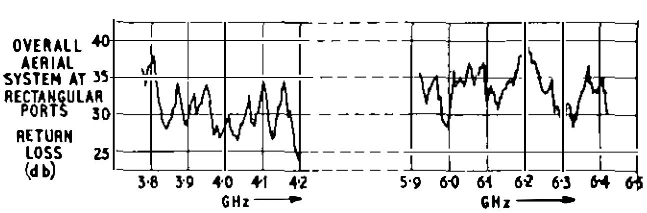
In general, all performance requirement set out in earlier sections have been met in the final field installation. Impedance-match measurements are shown in Fig. 7(*a*)–(*c*), respectively, for the larger aerial, the band-branching-unit assembly, and the complete aerial system, including



(*a*) Aerial



(*b*) Band-Branching Unit



(*c*) Overall Aerial System at Rectangular Ports

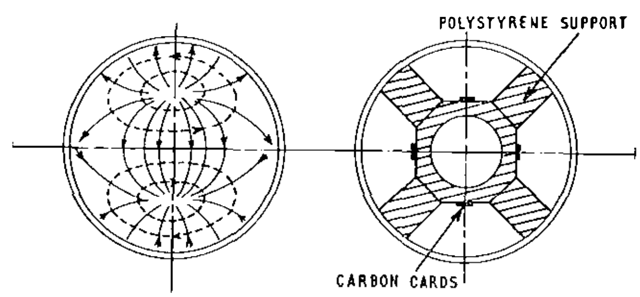
FIG. 7—AERIAL SYSTEM RETURN LOSS

230 ft of circular waveguide (the results are given as return loss = 20 $\text{Log}_{10}[1/T]$ dB, where T is the reflection coefficient).

Mode Conversion

Mode conversion from the dominant mode may take place due to variations in the guide cross-section in any part of the aerial system. In practice, the principal mode conversion experienced so far is to the E_{11} mode in the 6 GHz band, although in theory the particular circular-waveguide size used will propagate the E_{01} and H_{21} modes in both the 4 and 6 GHz bands, and the E_{11}, H_{01} and H_{31} modes in the 6 GHz bands.

The E_{11} mode conversion takes place in the horn aerial, the resultant echo signal being totally reflected by the 6 GHz transition, which is beyond cut-off to E_{11} modes, and reconverted to the dominant mode in the aerial. This E_{11} mode is suppressed by fitting a venturi section, in place of the slip link below the aerial, having a throat diameter (2·047 in.) which is below cut-off to the unwanted mode. The venturi section itself can cause a slight degree of E_{11} mode conversion from the main signal, and the effect of having mode reflectors at each end of the feeder run will result in mode trapping within the vertical-waveguide length. At critical frequencies, when a waveguide of given length becomes resonant, the unwanted-mode level can increase appreciably; to prevent this, an E_{11} mode electric-field attenuator, consisting of four carbon cards mounted parallel to the guide axis on a polystyrene spider, is fitted at the lower end of the waveguide run. A cross-section through the spider is shown in Fig. 8(*b*), correctly orientated in relation to the E_{11} field configuration of Fig. 8(*a*) to offer attenuation (10–15 dB per traverse) to the unwanted mode in either plane of polarization.



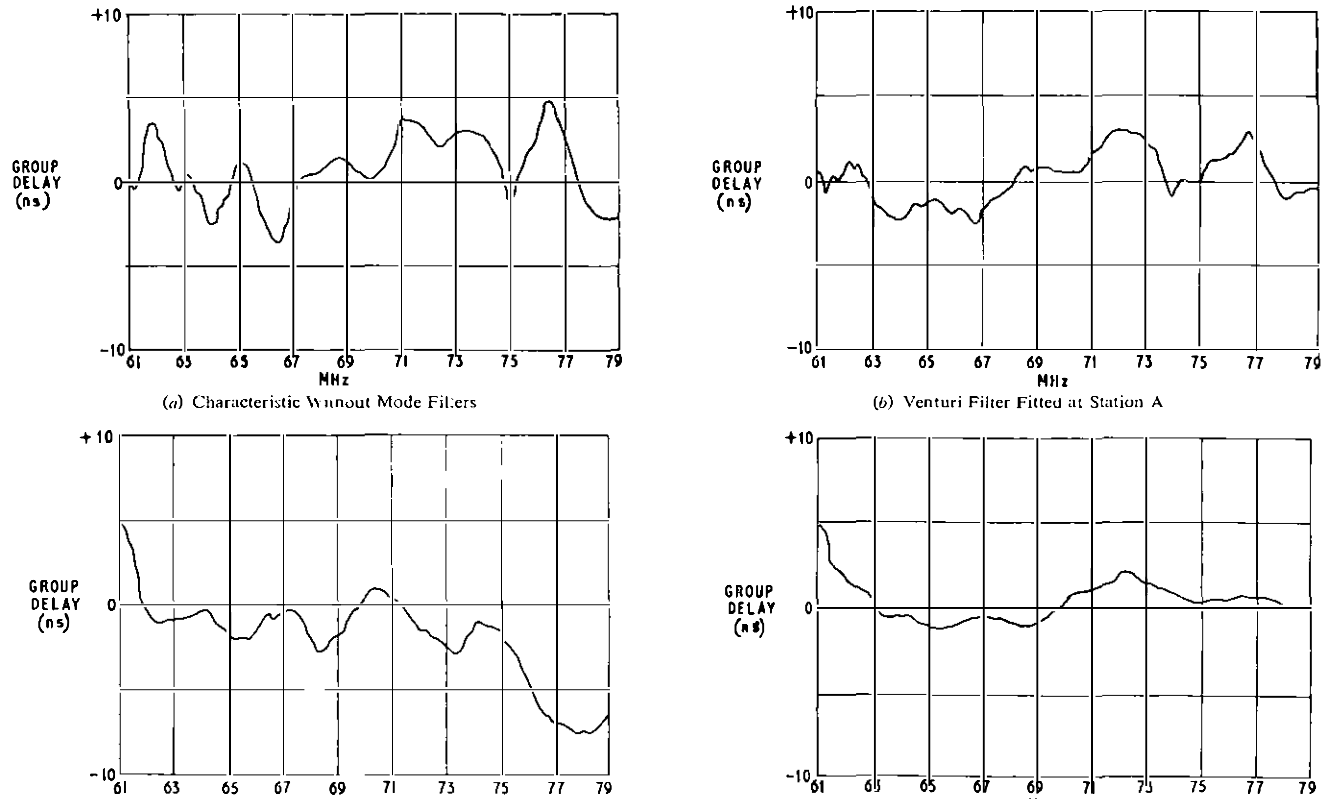
——— Electric-field lines
- - - - - Magnetic-field lines

(*a*) E_{11} Mode Field

(*b*) Section Through E_{11} Mode Attenuator

FIG. 8—E_{11} MODE FIELD AND ATTENUATOR

The presence of a feeder echo produces sinusoidal ripples on the group-delay/frequency characteristic, of a periodicity of $1/S$ cycles, where S is the echo delay in seconds. Fig. 9(*a*) shows the effect of two echoes on the overall group delay of a hop observed at i.f. An analysis of the curve shows two ripples of periodicities of 2·9 and 0·8 MHz to be present, which correspond to the particular delay of E_{11} mode echoes in the two feeder lengths. The progressive reduction of these ripples by mode filters is shown in Fig. 9(*b*)–(*d*), in this example resulting in a 900 pW reduction of intermodulation noise in one 3·1 kHz test slot at baseband.



(*a*) Characteristic Without Mode Filters

(*b*) Venturi Filter Fitted at Station A

(*c*) Attenuator Spiders Added at Stations A and B

(*d*) Venturi Filter Added at Station B

Circular-feeder length: 93 ft at Station A and 325 ft at Station B

FIG. 9—EFFECT ON GROUP DELAY OF E_{11} MODE FILTERING

CONCLUSIONS

The article has described the generally successful application of dual-band horn-aerial systems in the 4 and 6 GHz bands. Experience in equipping the initial route has shown the system-alignment costs to be significant, and that further expenditure on improved mechanical and electrical alignment aids might be justified for future systems.

First results indicate that the cross-polar discrimination of the aligned aerial systems is maintained reasonably, showing the structural rigidity under wind loading of the aerials, mountings and support structures to be adequate. In this respect, any horizontal twist of the tower structure is expected to have a greater effect on cross-polar discrimination performance than the same degree of vertical tilt.

It has been suggested that the aerial system described could be developed for use in the 11 GHz band. Apart from the redevelopment of 4 and 6 GHz band-branching units, and the suitability of existing repeater-station spacings and tower stabilities for use at 11 GHz, it is thought that the suppression of secondary modes at 11 GHz would be a difficult problem in that the circular feeder in use will support 17 different modes with cut-off frequencies below 11 GHz.

ACKNOWLEDGEMENTS

The author would like to thank G.E.C. (Telecommunications), Ltd., for permission to publish some of the details of aerials and system performance, and several colleagues for helpful criticism and for assistance in preparing some of the diagrams.

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An Improved Desiccator for Pressurizing Telecommunication Cables—Desiccator, Automatic, No. 1A

W. W. MOTT†

U.D.C. 66.047.8:621.315.211.4

This article describes an improved heat-reactivated adsorbtion-type desiccator for the supply of compressed dry air at exchanges or repeater stations with not more than eighteen cables, and also for use as a portable desiccator.

INTRODUCTION

THE Desiccator, Automatic, No. 1 was described in an earlier article on the pressurization of telecommunication cables.* This equipment was provided with alarm circuits to meet the requirements for the pressurization of such cables. In order to improve reliability and to obtain better access to components for maintenance purposes the Desiccator, Automatic, No. 1A has been developed. At the same time the output of air obtained from the desiccator at the required dryness has been substantially increased.

†External Plant and Protection Branch, Engineering Department.

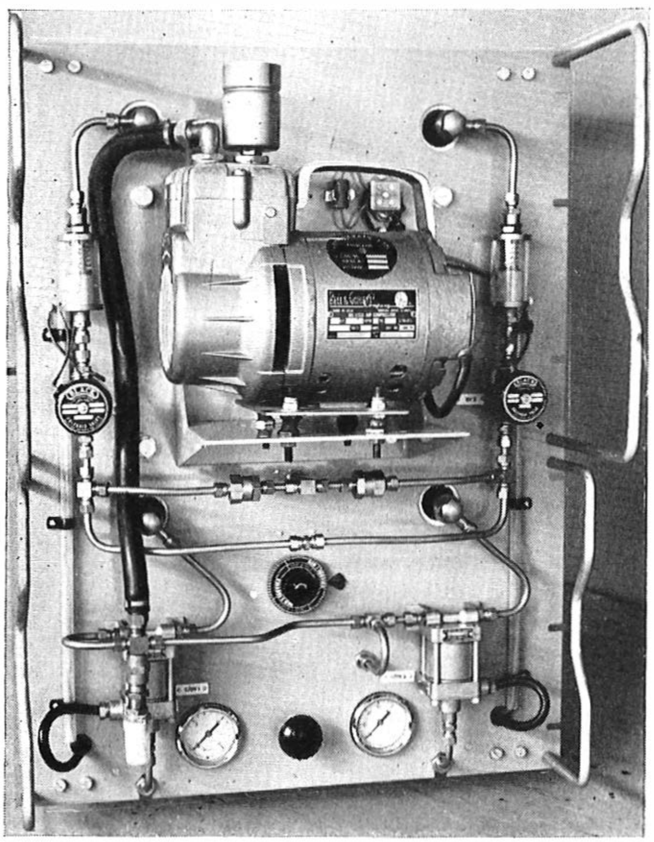
*WALTERS, J. R., KEEP, J. F., and CRAGGS, J. F. Pressurization of Telecommunication Cables, Part 2—The Supply of Dry Compressed Air. *P.O.E.E.J.*, Vol. 56, p. 25, Apr. 1963.

DESICCATOR, AUTOMATIC, NO. 1A

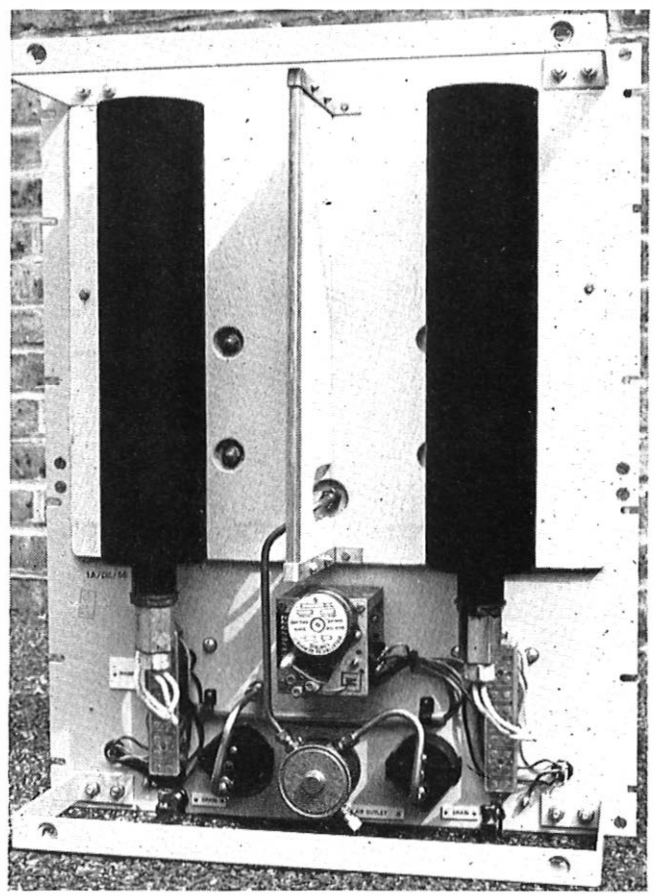
The complete Desiccator, Automatic, No. 1A consists of a heat-reactivated adsorbtion-type desiccator and a small compressor assembled on a 19 in. × $24\frac{1}{2}$ in. mounting plate. The compressor is enclosed in a sheet-metal cover lined with noise-reducing felt, and the remainder of the unit is protected by two expanded mesh covers. The rated output of the unit is 12 ft^3/hour at 9 lb/in^2 at a dew-point of − 20°C.

The complete desiccator, shown in Fig. 1, may be mounted on an apparatus rack, or on a trolley, together with a humidity-detector, starter direct switching, and pressure alarm, as a portable unit.

The compressor, driven by a $\frac{1}{12}$ h.p. single-phase a.c. motor, is of the single-cylinder reciprocating type, with a carbon-ring packed piston providing self lubrication and, thereby, ensuring oil-free air. The piston ring consists of a $\frac{1}{4}$ in. square-section carbon ring broken diametrically in half; in order to give the necessary seal the two halves are



(a) Compressor Side of Mounting Plate



(b) Adsorber-Bed Side of Mounting Plate

FIG. 1—DESICCATOR, AUTOMATIC, No. 1A WITH COVER REMOVED

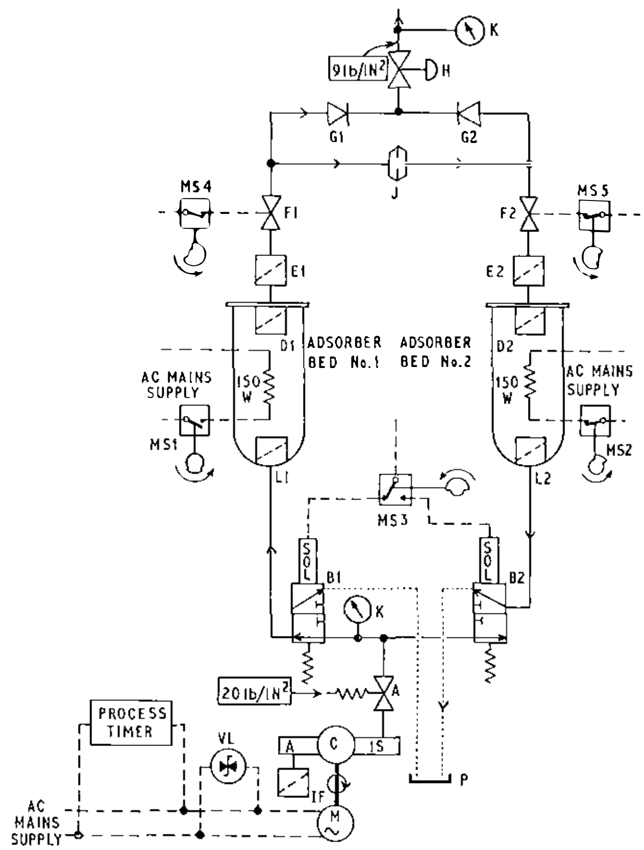
expanded on to the cylinder wall by means of a flat spring located in the base of the piston-ring groove.

The cylinder is a combined cylinder head and skirt, and is secured to the crankcase by three set-screws. Both the inlet and outlet valves are of the thin circular steel leaf type with the leaf held captive to the valve body by two small brass rivets. The valves are removed from the cylinder head by means of a spigot extractor tool, which has, at one end, two small pins that fit corresponding holes in the valve body. The inlet valve is removed by screwing anti-clockwise from the upper side of the cylinder head whilst the outlet valve is screwed clockwise out of the cylinder head from the under side of the head.

The air inlet to the compressor has a silencer which reduces noise, and also filters the air, thus reducing the wear on the valves. Filtering is achieved by means of three felt disks which require renewal periodically, and the valves and carbon piston ring should only require changing at yearly intervals. Lubrication of the compressor is reduced to a minimum by employing self-lubricating bearings and a sealed grease-filled big-end bearing.

Overload of the compressor is prevented by a clearance between the piston and the cylinder head, and electrical overload by means of a thermally operated device located inside the body of the motor. To keep the compressor within its operating temperature, a circulating fan is located in the compressor crankcase. Transmission of vibration from the compressor to the apparatus rack or trolley is reduced by the use of four rubber-bonded anti-vibration bolts, which secure the compressor to the shelf on which it is mounted.

The components of the Desiccator, Automatic, No. 1A are mounted on both sides of a mounting plate, thereby providing better heat dissipation from the compressor and the two drying beds. Space is available for large drying beds, each of which contain either $2\frac{1}{4}$ lb of silica gel or $3\frac{1}{2}$ lb of activated alumina. The larger beds and larger compressor provide a greater dry-air output than the earlier model. The two drying beds are used alternately to dry the air to the cables: one is in service for 8 hours, whilst the second bed is reactivated by heating and purging with dry air for 4 hours and cooling for 4 hours.



A—Relief valve. B1, B2—Three-way solenoid valves
C—Compressor. D1, D2—Internal perforated-brass filters
E1, E2—External sintered-bronze filters
F1, F2—Solenoid stop-valves. G1, G2—Non-return valves
H—Pressure regulator. J—Orifice restrictor
K—Pressure gauge. L1, L2—Internal sintered-bronze filters
VL—Voltage limiter. MS1–5—Cam-operated microswitches
IF—Compressor inlet filter-silencer
P—Purge container
— — — — A.C. mains connexions
—.—.——.—.. Purge pipework
——— —— Main pipework

FIG. 2—AIR AND ELECTRICAL CIRCUIT

OPERATION OF DESICCATOR

Fig. 2 gives the air and electrical circuit of the components. Electrical control is by means of a process timer consisting of a synchronous motor geared to rotate a shaft once every 16 hours. On the shaft are mounted five cams, which, in turn, operate five Elconite-contact micro-switches.

In Fig. 2, bed No. 1 is shown drying the air to the cables. Air from the compressor C passes through the 3-way solenoid valve B1 and filter L1, and is dried by flowing over the surface of the desiccant and out of the drying bed through filters D1 and E1. The dry air now passes through solenoid stop valve F1, and through non-return valve G1 to the pressure regulator H, which reduces the pressure from 20 lb/in² to 9 lb/in². The regulator keeps the output pressure constant and incorporates a bleed to reduce the pressure should the back-pressure from the cables exceed the regulated pressure.

Whilst bed No. 1 is drying the air to the cables, bed No. 2, containing moist desiccant from the previous drying cycle, is reactivated. A controlled flow of dry air, governed by the orifice restrictor J, is used to purge the moist bed No. 2. The dry air from the orifice restrictor passes through the solenoid stop valve F2, through filters E2 and D2, and through bed No. 2 containing the moist desiccant, which is now heated for 4 hours to approximately 150°C by the 150-watt heater element. The moisture-laden air passes out of the drying bed, through filter C2 to the 3-way solenoid valve B2, and into a suitable container vented to the atmosphere. At the end of the 4-hour heating period the heater is switched off and the solenoid stop valve F2 is released to cut off the purging air. The drying bed is left to cool for 4 hours to complete the reactivation cycle.

DESICCATOR COMPONENTS

The two 3-way solenoid valves are d.c. operated, and each have two rectifying diodes encapsulated in the valve base to provide the direct current. The core of the valve is of stainless steel, and the armature is heavily plated to withstand the corrosive effects of the moist air that flows through the valve during purging. A voltage limiter is wired across the motor terminals to protect the solenoid diodes against voltage surges as the compressor motor is switched on or off.

The two types of sintered-bronze filters have renewable elements, and are provided to protect the valve seats of the solenoid valves from desiccant dust. The perforated-brass filter located at the upper end of the drying bed is provided to prevent desiccant granules from falling out into the pipe line should the desiccator be turned upside down during transit or repair.

The process-timer controlling the sequence of operations has five fully adjustable cams, with adjustable actuator arms which operate replaceable microswitches having Elconite contacts to ensure reliable operation. The drive to the camshaft is via a clutch, to allow manual operation during routine maintenance.

The non-return valves are spring loaded and have nylon pistons: the large area of the valve seat and the light spring ensure a low operating pressure and low pneumatic resistance.

The heater elements are protected against corrosion with stainless-steel sheaths, and can be replaced.

CONCLUSION

Trials are in progress of a compressor that will fit in the space available in the desiccator but will, at the same time, give an increased output of dry air.

European Organization for Quality Control 11th Annual Conference, London, June 1967

U.D.C. 658.562:061.3

THE 12 months period which ended in October 1967 was the United Kingdom's "Quality and Reliability Year" sponsored by the British Productivity Council and the National Council for Quality and Reliability (N.C.Q.R.), of which the Post Office is a member. It was particularly appropriate, therefore, that the European Organization for Quality Control (E.O.Q.C.) should hold its 11th Annual Conference in London from 6 to 8 June 1967. The conference was organized on behalf of the host country by the British Productivity Council. The N.C.Q.R. is affiliated to the E.O.Q.C. and the American Society for Quality Control (A.S.Q.C.). There is close co-operation between E.O.Q.C. and A.S.Q.C., and plans are being prepared for the establishment in 1971 of a world-wide "International Association for Quality."

The conference was attended by over 800 delegates from 26 countries. There were strong delegations from the United States and Japan, including the leading American exponents of quality control. The British Post Office Engineering Department was represented by a Deputy Director and three senior engineers from the Test and Inspection Branch.

The theme of the conference was "The Practical Realization of Quality and Reliability." There were eight working sessions, each consisting of a number of papers followed by a discussion period. The titles of the sessions were "Management Policy," "Q. & R. in Design," "Reliability Assurance," "Purchasing," "Planning for Production to Specification," "Producing to Specification," "Benefiting by User experience to improve Reliability," and "The Customer's Role."

The fundamental principle behind quality control is to "get it right first time" on the production line, instead of concentrating productive effort on securing high-volume output and relying on subsequent inspection and correction to locate and remove defects. It is very apparent that, by applying method study on the production lines to identify and remove causes of defective production and by using statistical sampling techniques to provide early warning of trouble, it is possible not only to improve the quality of the product, but to reduce costs and increase productivity by eliminating much of the effort spent in finding and correcting defects, and the cost of scrap. These principles are applicable to all industries and services, including the telecommunications industry, where many of the production practices were established between the wars and which is now undergoing rapid expansion to meet the increasing requirements of the Post Office. There is ample scope here for the introduction of effective quality control to the mutual benefit of the Post Office and the industry.

To expedite this process, in the case of telephone and telegraph apparatus, exchange equipment and cable, it has now been made a condition of contract that a contractor shall employ quality-control measures which are to the satisfaction of the Engineering Department. This condition of contract will soon be extended to transmission equipment and other supplies.

One outstanding message to come out of the conference was that "quality is everyone's business": from the board-room to the shop floor; designer, producer; customer, supplier. Success will only be achieved if everyone plays his part in full. In large firms and organizations such as the Post Office, where there is extensive dispersion of responsibility, the problems of co-ordination are immense, but must be solved. If the Post Office is to succeed in its new status as a public corporation it will have to ensure that everyone, from market research to design, manufacture, purchasing, installation and maintenance, is "involved" in providing the best quality service at a price the public is prepared to pay.

This was one of the themes of an earlier conference held at Blackpool in November 1966 to initiate the Quality and Reliability Year. In this there was special emphasis on quality in the service industries; the Post Office, as a major service industry, was represented, and provided a paper on quality control and quality improvement in the automatic telephone service. This paper was well received and was quoted in the final report on the conference, which ended with the thought that the technique of quality control must remain flexible to meet technological changes and changes in demand from customers, thereby ensuring still better quality at acceptable prices.

J.B. and T.F.A.U.

Measuring Quality of Service on Trunk Routes

R. A. FRANÇOIS and E. R. HOLLIGON†

U.D.C. 621.395.374:658.562

As the subscriber trunk-dialling facility is extended the quality of service given on trunk routes becomes correspondingly more important. The article describes a way in which quality of service measurements can be made, enabling more effective control to be exercised over the service on trunk routes.

INTRODUCTION

WITH a system of demand working in which trunk calls are set up under the control of a telephone operator, subscribers are shielded to some extent from the effects of the poor performance of any link that might be encountered on the trunk routes. The quality of service under this system of trunk working is controlled mainly by systematic and comprehensive routine testing, supplemented by operator reports of difficulty, engineering interpretation and action on service observations, and, where necessary, by special selective test programs. It was essential before subscriber trunk dialling (S.T.D.) was introduced generally that the adequacy of routine-testing and fault-reporting arrangements should be examined to ensure that, if properly carried out, they would be capable of maintaining the quality of service to which subscribers had become accustomed; routine-testing arrangements could be modified or augmented if this was found to be necessary. Investigations confirmed that the existing routine-testing arrangements were adequate, but that they should be reinforced with some form of continuous route-performance indicator which would enable the officer in charge of a trunk switching unit to be continuously aware of the service given on any route outgoing from his unit and to initiate any remedial action considered necessary.

Requirements of Route-Performance Indicator

The major essentials of the route-performance indicator are that it should be capable of introduction on a national basis in order to obtain uniform measurements throughout the trunk switching network, and that it should cover the following types of trunk links: zone centre to zone centre, zone centre to group switching centre, and group switching centre to group switching centre. Furthermore, to minimize the operational cost and eliminate human errors, the final scheme adopted should be automatic and be capable of producing information reliably and quickly.

METHOD OF OBTAINING ROUTE-PERFORMANCE INDICATOR

Because of the need to introduce with the minimum of delay a scheme that would enable the officer in charge of a trunk switching centre to keep pace with the service on an expanding trunk network, as the S.T.D. facility was extended, the decision was made to provide the route-performance indicator in two quite separate stages: first, the interim stage, to be implemented immediately and to provide the indicator using, as far as possible and practicable, existing facilities; then the final stage, in which the indicator would be provided using automatic methods, after the necessary development work and field trials had been completed.

Interim Scheme

For the interim scheme a system using a continuing program of test calls, originated by selected testing operators to final-selector test numbers, was decided upon because this was the most readily available and satisfactory method of providing the route-performance indicator. This scheme, known as trunk-line dialling tests, was launched, and is still in current use. Results of the test calls, classified where necessary in various fault categories, are recorded by the testing operator and the test sheets are submitted daily to a Headquarters control for analysis, publication and distribution of national results. The scheme is divided into two sections: the first deals with the trunk links between zone centres, and is under the direct control of a Headquarters group; the second section deals with other types of trunk links, and is controlled by the individual Regions concerned. Attention was directed in the first instance towards implementing the scheme on zone-centre to zone-centre links because that particular section of the trunk network carries the bulk of the long-distance subscriber-dialled traffic.

For the zone-to-zone routings 20 exchange test numbers are nominated at each zone centre and checked periodically to ensure that they are maintained in first-class working order. The number of test calls originated on any route per day is 20 for circuits obtained from selector levels, or is one per circuit for manually-selected circuits, with a minimum sample of 20. The program is arranged to pass more calls in the busy hour than during periods of light traffic, and is operative during normal working hours (8 a.m. to 6 p.m.) Monday to Friday. The sample spans a fortnightly period, during which time a minimum of 200 test calls is passed over each route outgoing from any zone centre. The results are analysed at Headquarters and a number of control documents produced.

The system is designed and implemented to reduce to a minimum the delay in providing each zone centre and management with a statement of outgoing-route and incoming-route performances and of national averages. The nature and size of the sample make it desirable that the results should be interpreted as trend indicators, and that any remedial action should be initiated only after several results have been compared. The spirit of inter-Regional and inter-exchange co-operation which this scheme fosters, so far as testing and maintenance liaison work is concerned, has proved more and more valuable as the S.T.D. facility has been extended and as it has been generally realized that the outgoing S.T.D. quality of service from any exchange is governed mainly by the performance of the trunk routes and exchanges to which it has access.

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Final Scheme

The main advantage of the trunk-line dialling-tests program was that it was capable of being introduced with a minimum of delay, but, as this form of measurement is required as a continuous feature of maintenance, the next stage was for equipment capable of making similar measurements by mechanical means, which would be more economical in service and would eliminate any human-error factors. Equipment of this type would not usurp the routine and fault-reporting procedures in current use, but, on the contrary, could serve as a useful guide to their effectiveness and execution. It would also be used in addition to centralized service-observation measurements, which, with the introduction of S.T.D., were changed by new types of circuits, methods of measurement, and processing to provide statistics capable of being used for more effective control than was previously possible. The equipment designed to automate the trunk-line dialling-tests program is known as trunk-route service-measuring equipment, of which there will be two versions: one, a rack-mounted equipment (see Fig. 1), has been designed specifically for use on the trunk links between zone centres; the other, a transportable equipment (see Fig. 2) with a reduced number of facilities, is intended for use on all other types of trunk links.

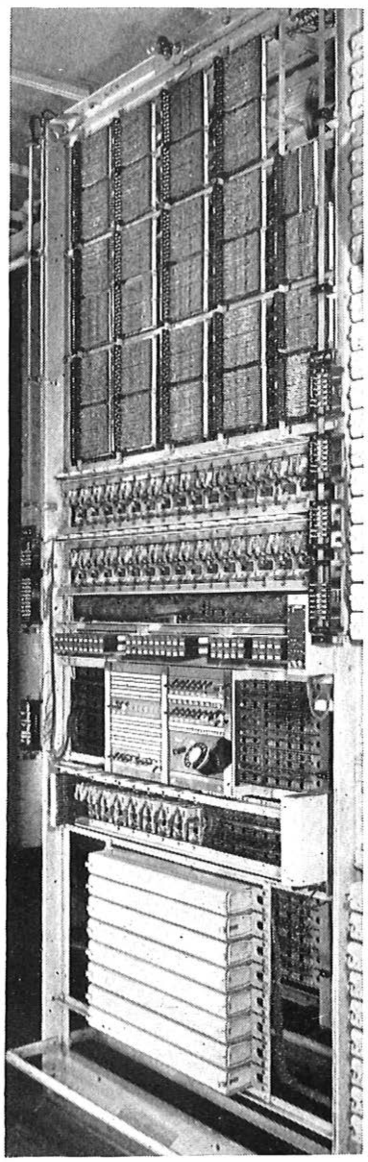


FIG. 1—RACK-MOUNTED TRUNK-ROUTE SERVICE-MEASURING EQUIPMENT

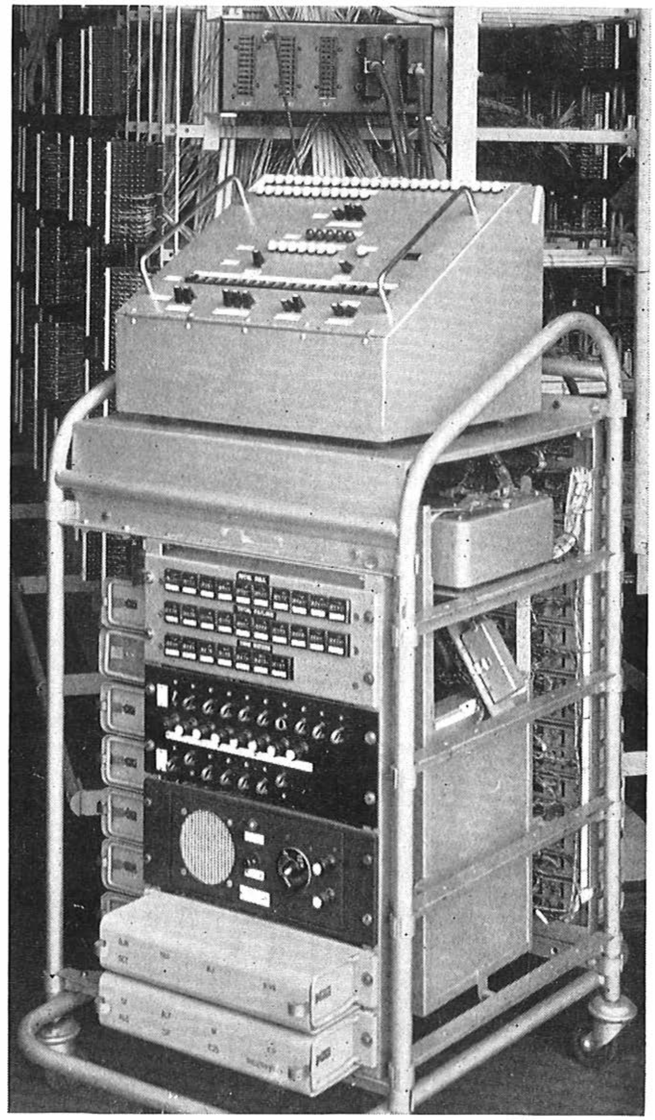


FIG. 2—TRANSPORTABLE TRUNK-ROUTE SERVICE-MEASURING EQUIPMENT

The basic facilities of the rack-mounted trunk-route service-measuring equipment include the origination of test calls from subscribers' calling equipments, or from selectors or relay-sets. Test calls can be originated on a maximum of 25 routes to distant final-selector numbers, and provision is made for a maximum of 25 final-selector numbers per route. The equipment can be programmed using clock control to start a test cycle every hour during normal working days, and can also be programmed to vary the number of cycles per hour up to a maximum of 10 test cycles; the program ensures that successive calls on each trunk route are to different test numbers. The received signals are identified, and the results are recorded on meters for each route. The equipment is capable of identifying the signals detailed later in Table 1, any or all of which, by suitable strapping, may be recorded as a call failure. Experience shows that the facility of recording separately on meters for any one route all the tones detailed in Table 1, is a valuable aid when a complete assessment of the performance of an individual route is required. The operation of alarms and cessation of testing are catered for in the event of a failure of the measuring equipment.

The transportable trunk-route service-measuring equipment, which is trolley mounted, differs slightly from the rack-mounted version in three respects: the method of connexion to the exchange equipment, test-call program capacity, and program storage. Its access equipment is connected via plugs and cords to an access panel mounted on an intermediate distribution frame, which is wired out to the point in the exchange from which it is intended to originate the test-call program, e.g. subscribers' spare calling equipment. In the rack-mounted version, access to the exchange equipment is effected by means of permanent cabling. For the transportable version, which is intended for use at the smaller trunk centres, the test-call program capacity is limited to a maximum of 10 calls on each of 10 different routes; the program is stored on punched paper tape, using a 5-unit code, and a tape reader is associated with the sending elements.

The success of the trunk-route service-measuring equipment depends, to a very large extent, on the performance of the tone-detection devices and test-number circuits. Consideration was given during the development stages to using two quite separate tone receivers, one operating basically at 400 Hz, for the identification of standard supervisory tones, and the other operating at, say, 1,600 Hz to identify test tones, which would have inevitably involved a redesign of the test-number circuits. For reasons mainly of economy it was decided to implement a scheme using one tone receiver operating at 400 Hz.

In an attempt to increase overall reliability an investigation was initiated into the efficiency of the final-selector test-number circuits in current use. Basically, the current version of test-number circuits provides alternate called-subscriber-answer (C.S.A.) and called-subscriber-clear (C.S.C.) signals, the durations of which are approximately equal and of 1·5 seconds. During the C.S.A. condition a tone from the continuous ring-tone supply, which has a basic 400 Hz content, is sent to line. The repetition of C.S.A. and C.S.C. conditions over a trunk link, using either Signalling System A.C. No. 1 or No. 9, tends to mutilate the test tone and extends the time required by the tone-detection devices to recognize the tone. In view of this, the standard test-number circuit for use in conjunction with the trunk-route service-measuring equipment will incorporate the facility of extending a permanent C.S.A. condition after initial seizure. The tone sent out to line for approximately two seconds will be derived from the standard number-unobtainable-tone supply and will be followed by a 1-second silent period.

OUTLINE OF OPERATION

The block schematic diagram of Fig. 3 shows the main functions of the equipment; the circuit arrangements adopted on the rack-mounted equipment are described below, and are followed by those of the transportable version where these differ.

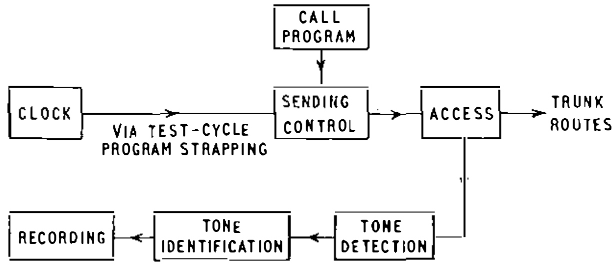


FIG. 3—BLOCK SCHEMATIC DIAGRAM OF TRUNK-ROUTE SERVICE-MEASURING EQUIPMENT

Clock, Access and Sending

The clock circuit consists of a group of uniselectors controlled by 30-second pulses from the exchange master clock. These uniselectors in turn control the sending of the test cycles via the test-cycle program strapping-field.

Three-wire (battery or earth testing) or two-wire access, under control of keys, is provided by conventional circuits. When access to an outlet has been successfully established, the digits appropriate to the call are sent to line. These pulses are of standard form, i.e. 10 pulses/second with a 66 per cent break period, derived from a transistor-type multivibrator, control of the digit value and the interdigital-pause length being exercised by a pulse counter using Post Office type-10 relays.*

Program Control

Control of the program of calls is exercised by a group of uniselectors, the arcs of which are wired to a field of tag blocks where strapping to the required digits may be made, as indicated in Fig. 4.

A digit switch (DS), on positions 1–6, controls connexion of an earth to the wipers of a routing-digit (RD) switch, from which up to six routing digits may be wired, those not required being strapped to the digit cut-off (DCO) terminal in the conventional manner. Switch RD is stepped on completion of each call, its 25 positions being associated with the 25 trunk routes made available to the measuring equipment.

Control of the local digits is from positions 7–14 of the DS switch, the earth being connected via arcs of local-digit A and B (LDA and LDB, respectively) switches. The LDA and LDB switches, which step in unison at the end of each call, have their arcs wired to wipers of local-digit (LD) switches. There are 25 LD switches in all, and from their arcs up to eight local digits per call may be wired. With these uniselectors standing on position 1 the local digits appropriate to the first test number associated with each of the 25 trunk routes will be sent; this constitutes one test cycle.

As each of these calls is completed, the associated LD uniselector is stepped in preparation for the next test cycle. This cycle will consist of the same sequence of routing digits with a different series of local digits, the latter being wired from position 2 of the LD switches. In this manner the complete program of 625 calls (25 test cycles) is available to the measuring equipment in sequence.

In the transportable version of the measuring equipment, where a program of only a 100 calls is required,

*Rogers, B. H. E.: The Post Office Type-10 Relay. *P.O.E.E.J.*, Vol. 51, p. 14, Apr. 1958.

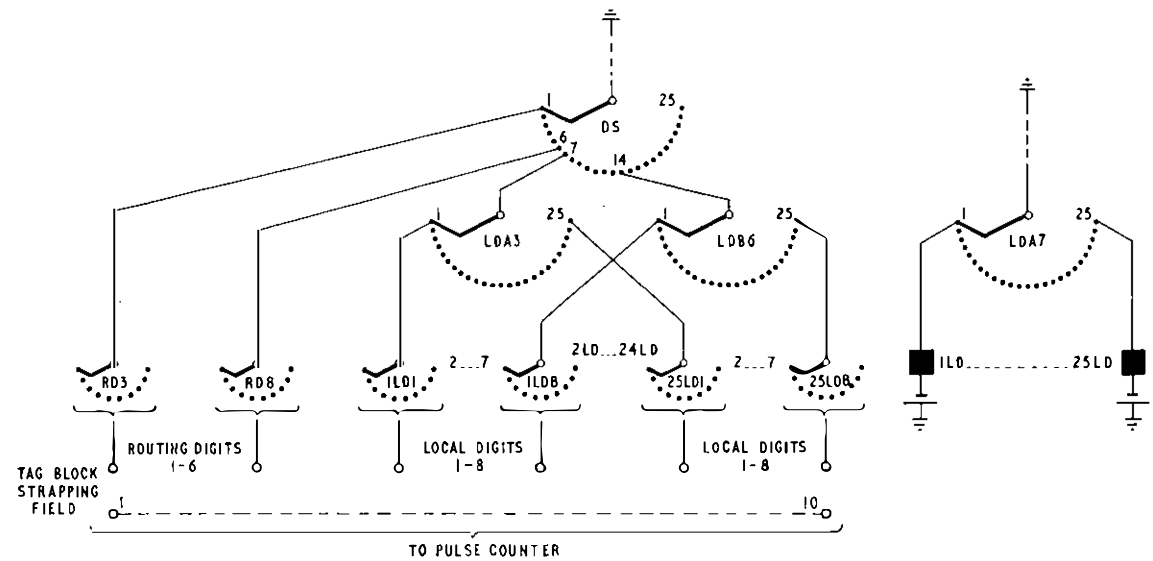


FIG. 4—CIRCUIT ELEMENTS OF PROGRAM-CONTROL ARRANGEMENTS ON RACK-MOUNTED EQUIPMENT

these arrangements have been replaced with a punched paper tape on which the digital information is stored in a 5-unit code.

The tape provides a sequence of codes consisting of a start signal, a route code, and routing and local digits for each of the 100 calls. The circuit arrangements are shown in Fig. 5, the codes chosen for the route code and

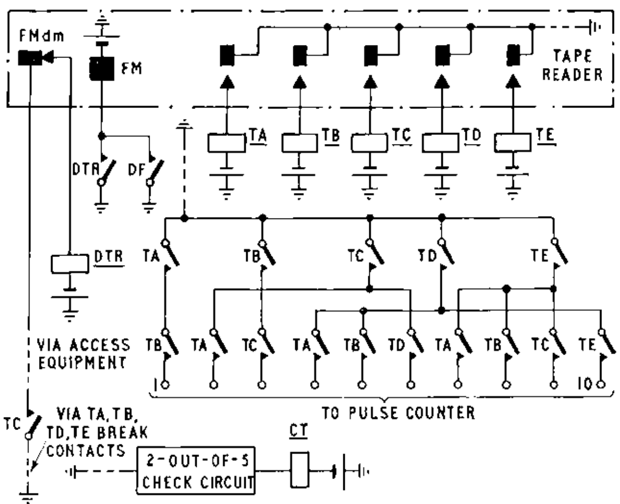


FIG. 5—PROGRAM-CONTROL CIRCUIT ON TRANSPORTABLE EQUIPMENT

the routing and local digits being such that in each case two of the five TA–TE relays are operated, thus permitting a two-out-of-five check to be made. For the start signal a code is chosen which results only in relay TC operating, while an end-of-cycle signal, which occurs at the end of each sequence of 10 calls, causes operation of relay TA only. Where required, a long interdigital pause may be inserted after any digit by using a special code which results in operation of all five relays.

When access to an outlet has been established, and provided relay TC only is operated, relay DTR operates to control operation of the tape-reader feed-magnet. The tape therefore moves to a position where a route code is punched and the appropriate two of the TA–TE relays operate. Provided the two-out-of-five check is satisfactory, relay CT operates, and starts the pulse counter which controls the positioning of a route uniselector (not shown) in accordance with the code relay markings. This uniselector is subsequently used to control the recording of the result of the call on the meters associated with the route, as described later. When positioning is complete relay DF operates, and is used to control stepping of the tape to the next position, the relays appropriate to the route code release, and those appropriate to the first routing digit operate. Meanwhile, the counter is reset and is used to control generation of an 800 ms interdigital pause (while this is not in fact required after the route code, it is necessary after all digital codes, and circuit simplification results by generation in all cases).

The routing and local digits are sent under the control of the pulse counter, and on completion of a sequence of 10 calls, i.e. one test cycle, the end-of-cycle signal prevents further sending unless the program-control setting indicates that further cycles are to be sent.

Tone Detection

As the sending of each call is completed, the line wires are switched to the input of a tone detector, the circuit of which is shown in Fig. 6. The tone detector is designed to receive signals of −30 dBm or greater, over a frequency range of 350–500 Hz. This bandwidth is necessary to ensure operation to ringing tone, which may be derived either from mixing 400 Hz and 450 Hz or by modulation of 400 Hz with 25 Hz, and to cater for the specified tolerances of the machines generating the tones.

The input to the detector is via a transformer; the connexion of resistor R1 across the secondary winding, in conjunction with the other first-stage components, ensures an input impedance of approximately 600 ohms. Rectifiers MR1 and MR2 limit the signal level to prevent overloading of the early stages.

Transistors VT1 and VT2, with associated components, form conventional *RC*-coupled amplifier stages; to provide single-stage negative feedback the emitter

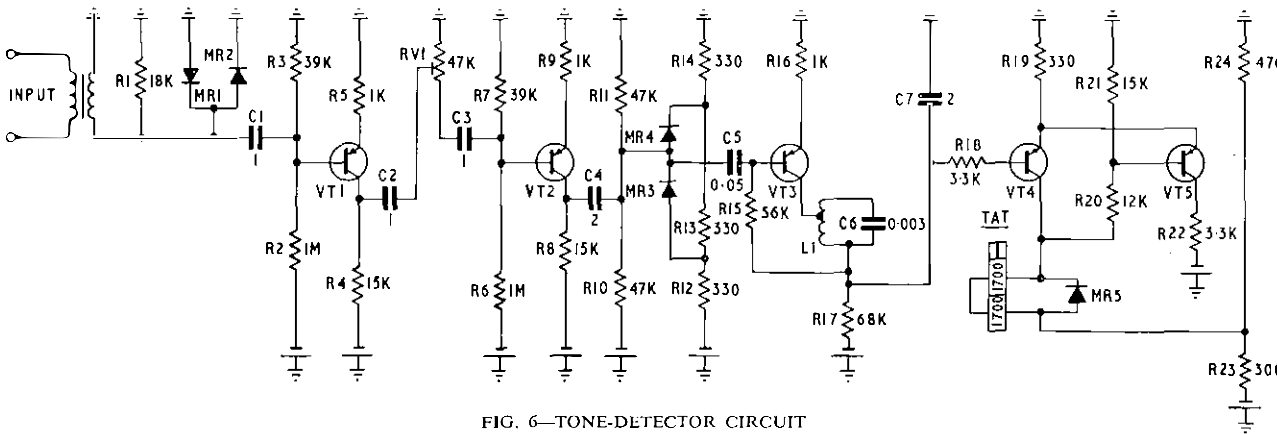


FIG. 6—TONE-DETECTOR CIRCUIT

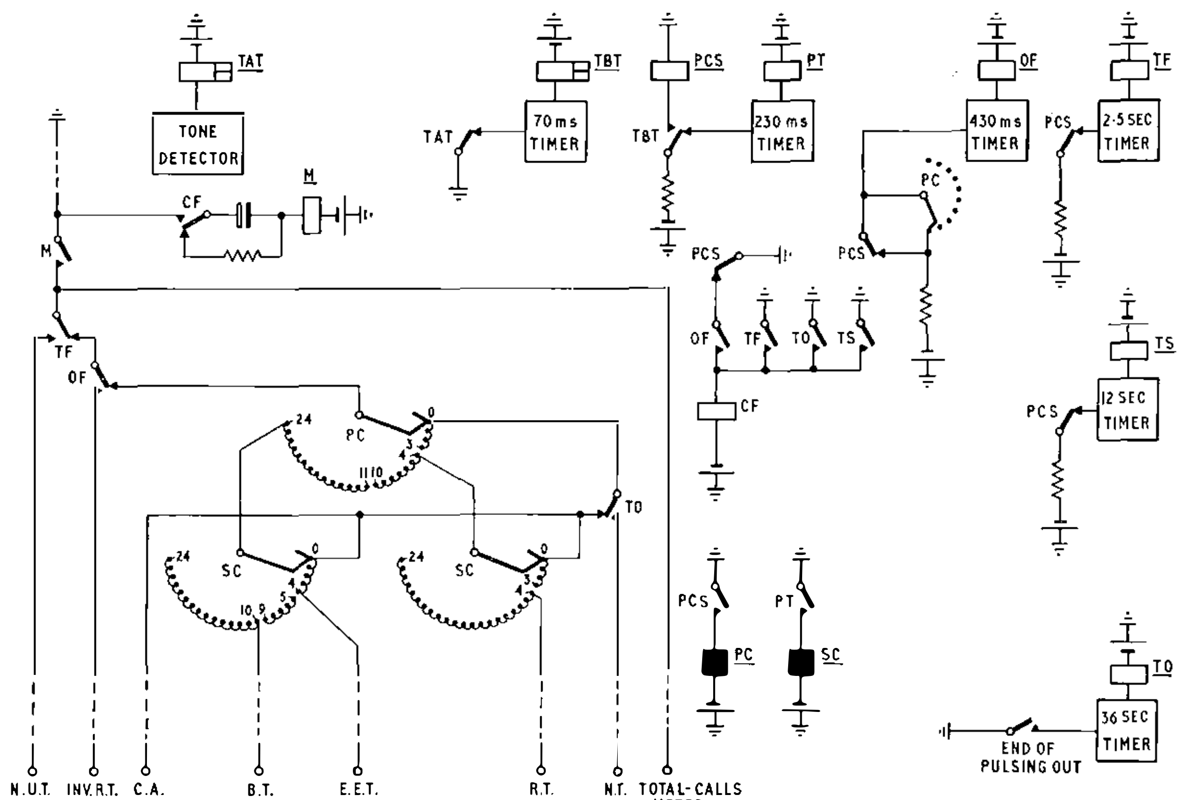
resistors are not bypassed. Potentiometer RV1 s a pre-set control used to adjust the sensitivity of the detector.

Rectifiers MR3 and MR4, together with resistors R12–14, provide further limiting of the signal (to about -25 ± 8 volts) before it is passed to the discriminator stage.

Transistor VT3 in the discriminator is normally conducting, and the negative half-cycles of the signal are, therefore, ineffective, but the positive half-cycles inject energy into the tuned circuit. At the tuned frequency the changes in potential, which are integrated across capacitor C7, are of sufficient magnitude to switch the Schmitt trigger (transistors VT4 and VT5). Consequently, relay TAT operates, sufficient backlash being provided in the trigger design to prevent erratic switching in the event of slight variations in level of the received signal.

Tone Identification

Identification of the signals received by the tone detector is achieved by a combination of timing circuits and uniselectors; a simplified diagram of the arrangements is shown in Fig. 7. The signals it is necessary to identify are listed in Table 1, any of which may be mutilated by the one-second-in-five chopping which occurs on some Signalling System A.C. No. 1 circuits.



N.U.T.—Number unobtainable tone. INV. R.T.—Inverted-ringing tone. C.A.—Congestion announcement. B.T. Busy tone. E.E.T. Equipment-engaged tone. R.T.—Ringing tone. N.T.—No tone.

FIG. 7—TONE-IDENTIFICATION CIRCUIT

Relay TAT operates for each period of received tone, or tone simulation from a congestion announcement, and starts operation of a 70 ms timing circuit controlling relay TBT. Any signals of longer duration than 70 ms cause operation of relays TBT and PCS; signals of shorter duration are ignored. This initial timing discrimination permits the use of a tone detector having short response and release times, this being necessary to ensure that the signal-imitation pattern encountered on connexion to a congestion announcement is recognized but not confused with other signals.

TABLE 1
Signals Requiring Identification

Signal	Periodicity
Busy tone	375 ms on, 375 ms off
Equipment-engaged tone (Note 1)	400 ms on, 350 ms off, 225 ms on, 525 ms off
Inverted-ringing tone, i.e. test number (Note 2)	2 seconds on, 1 second off
Number-unobtainable tone	Continuous
Ringing tone	400 ms on, 200 ms off, 400 ms on, 2 seconds off
No tone	
Congestion announcement	

Notes: 1. The level of the 400 ms period of tone is −6 dBm with respect to the others.
2. This is a true inversion of ringing-tone periodicity when derived from a machine, but is as shown above when derived from a test-number circuit.

The operation of relays TBT and PCS starts a number of timing circuits. A 230 ms timer controls operation of relay PT, which, therefore, registers all tone periods of longer duration than 300 ms; similarly, a 430 ms timer controls relay OF, registering any tone period greater than 500 ms (except the first, which is masked by uniselector PC). A 2·5-second timer controlling relay TF is used to register receipt of any tone period of this duration, while a 12-second timer, the operation of which is locked once started, controls relay TS and, thereby, the maximum period for which an incoming signal is inspected.

Each operation of relay PCS is registered by the stepping of a primary-count (PC) uniselector, and of relay PT by a secondary-count (SC) uniselector.

The received signal is now identified in the following manner. If any signal is received of longer duration than 2·5 seconds, indicated by operation of relay TF, the receipt of number-unobtainable tone may be registered and further inspection becomes unnecessary. Similarly, receipt of any signal of a duration lying between the limits of 500 ms and 2·5 seconds, indicated by release of relay PCS with relay OF operated, registers inverted ringing tone. If receipt of neither of the above tones has been registered at the end of the 12-second period, the position of uniselectors PC and SC is examined and the remaining signals identified as shown in Table 2.

In addition, a 36-second period, timed by a uniselector controlled by 1-second clock pulses and commencing operation at the end of pulsing out, terminates the call if no signals have been received and a no-tone is registered.

When tone identification is complete, relay CF is operated, completing a circuit to pulse-operate relay M to record the result.

The timing circuits employed in the tone-identification circuit are *CR* charging circuits, controlling a transistor Schmitt trigger in the 70 ms timer, and thyratrons in the longer-duration timers. In the smaller transportable measuring equipment, transistors are used throughout.

TABLE 2
Signal Identification

Uniselector Position		Tone
PC	SC	
4–10	4–9	Ringing tone
11–18	5–9	Equipment-engaged tone
11–18	10–18	Busy tone
1–3	0	Congestion announcement
4–10	0–3	Congestion announcement
11–18	0-4	Congestion announcement

Recording

The tone-identification tags shown in Fig. 7 are wired via the arcs of a uniselector (not shown), which steps at the end of each call. The 25 sets of tags are, therefore, associated with the 25 trunk routes, and each set may be strapped as required to the total-failures meter (TFM) appropriate to the route. A total-calls meter (TCM) for each route is also provided, and this, together with meter TFM, if appropriate, is operated when relay M operates on completion of tone identification. One complete set of meters is provided to permit a full analysis to be registered on a single route if required, the meters being strapped to each of the tone-identification tags associated with the route concerned.

In the transportable equipment a simpler arrangement is adopted, total-calls and total-failures meters being provided for each of the 10 routes, but strapping to the total-failure meters is common for all routes, only one set of terminals being provided. Selection of routes for full analysis is made by means of links.

CONCLUSIONS

The introduction of the trunk-route service-measuring equipment will enable officers in charge of trunk switching units to be continuously aware of the quality of service given on outgoing routes. The routes interconnecting zone centres will be served by the rack-mounted version, and the programming, processing of results and dissemination of information will be centrally controlled. Regions will make use of the transportable version for other trunk routings as experience dictates, and arrange for the dissemination of control information accordingly. If a comparison of a series of results indicates a deterioration in service on a particular route it is envisaged that controlling officers will initiate a concentrated investigation of that route using all the necessary maintenance aids, e.g. digit-display equipment, trunk-circuit test-call senders, call-failure detection equipment in the larger centres, or the transportable trunk-route service-measuring equipment, using the hold and trace facility, in the smaller centres.

It is hoped that the information provided by the trunk-route service-measuring equipment will be used, in conjunction with normal routine-testing and fault-recording procedures, centralized service-observation results and traffic-sampling equipments, to reduce to a minimum the length of time that a faulty piece of equipment concerned with trunk calls can remain undetected in service, and will assist in ensuring that the best possible trunk service is given, commensurate with the limits imposed by cost and availability of manpower.

Notes and Comments

Retirement of J. W. H. Freebody, Whit. Sch., B. Sc. (Eng.), A.C.G.I., D.I.C., C.Eng., F.I.E.E.

Notice of John Freebody's retirement on 25 July 1967, so soon after his promotion to Deputy Director of Engineering as head of the recently formed Long-Range Systems Planning Unit (see *P.O.E.E. Journal,* Vol. 59, p. 135, July 1966), came as a great surprise to his many friends and colleagues.

At every stage of his career, he has impressed those with whom he has worked by his energy, enthusiasm and kindliness. He has made his mark in the allied fields of data and telegraphy. His work during the early months of the formation of the Long-Range Systems Planning Unit has been incisive and determinant. For the pattern that he mapped out is now being developed and shaped into the technical policy of the 1970s and, maybe, even the 1980s.

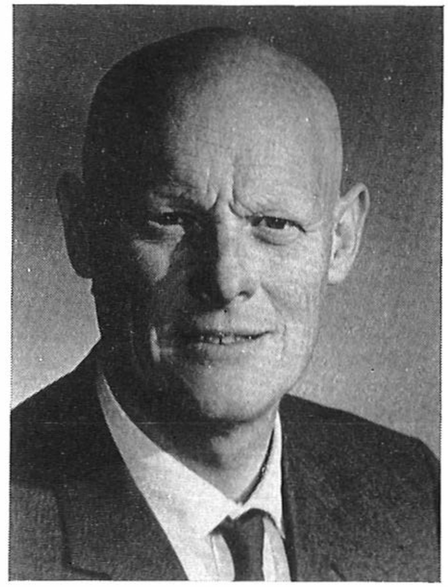
On reading this he will be characteristically modest and refer to the "good chaps" around him. But this is to underplay, and understate, his own special contribution.

We all wish him relaxation, satisfaction, and every happiness in the days ahead.

J.H.H.M.

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

Mr. Williams' promotion to Deputy Director of Engineering in charge of the Long-Range System Planning Unit will have given pleasure to his many friends in the Post Office and Industry, and recognizes the major part which he has already played in the Unit's activities. When he was appointed Staff Engineer as a founder member of the Unit some 15 months ago, he brought with him a fund of information on transmission and allied matters based on a wide-ranging career in the Lines Branches (see *P.O.E.E. Journal,* Vol. 59, p. 221, Oct. 1966).



While his wealth of experience in the transmission field is a great asset to the Unit, perhaps more important is his far-sighted, logical and balanced approach to the many challenging problems of long-range systems planning. These are particularly severe at a time when many potentially powerful, but as yet unproven, advances in technology seem likely to lead to drastic changes in the scope and content of the country's telecommunications networks, and to do away with many of the traditional boundaries such as that which has existed between transmission and switching in the past. In these circumstances, long-range planning involves the evaluation of many varied and complex technical developments, and an appreciation of their inter-relationships and basic objectives. Close co-operation with specialists in many fields is essential, and requires an informed and understanding approach to their problems and technical aspirations. Constructive discussions, often on intricate, speculative and controversial topics, are a major part of the Unit's activities.

It says much for Mr. Williams' intellectual and personal qualities that, in spite of all the problems, there can be every confidence that under his leadership the activities of the Unit will lead to the formulation of a comprehensive plan for the future development of the telecommunication system: a sound but far-reaching plan, both practical and imaginative.

L.R.F.H.

Post-Graduate Awards, 1967

The Post Office is making a number of post-graduate awards each year to selected staff. These awards will be tenable at universities that have facilities for research or for advanced studies relevant to Post Office problems, initially in telecommunication science and engineering. In appropriate cases the awards will enable the holders to qualify for M.Sc. or Ph.D. degrees. The primary object is to further research and to develop expertise of special value to the Post Office.

The Post Office awards were first made in 1966; the officers selected for the 1967 awards, and their awards, are listed below.

Mr. B. L. Nuttall, B.A., Executive Engineer, External Plant and Protection Branch, Engineering Department, has been awarded a 1-year M.Sc. course in systems engineering tenable at the University of Surrey.

Mr. P. James, Assistant Executive Engineer, Post Office Research Station, graduate of the Institution of Electrical Engineers, has been awarded a 1-year M.Sc. course in electronic-circuit and systems engineering at Bath University of Technology.

Mr. R. Hanks, B.Sc., Assistant Experimental Officer, Post Office Research Station, has been awarded a 1-year course leading to the Diploma for Membership of the Institute of Chemical Engineers tenable at University College, London.

Mr. J. H. Fletcher, Dip. Tech., Executive Engineer, Postal Engineering Branch, Engineering Department, has been awarded a 1-year M.Sc. course in automatic control systems tenable at Imperial College, London.

Mr. P. A. Watson, B.Sc., Scientific Officer, Post Office Research Station, has been awarded a 1-year Ph.D. course at Durham University. This final-year Ph.D. course, entailing full-time attendance at the University, follows 2 years' research at the Post Office Research Station on parametric amplifiers.

Mr. T. F. Smith, B.Sc., Executive Engineer, Post Office Research Station, has been awarded a 3-year Ph.D. course in economic and theory aspects of general-purpose telecommunication systems, at the University of Essex.

I.T.U. Seminar on "The Telephone Service," London, September 1966

A note describing the I.T.U. Seminar which was held in London during September 1966 was included in the January issue of the Journal, (Vol. 59, page 282). The papers given at the Seminar have now been published in two-volume form by the British Post Office, and copies have been circulated to all member countries of the I.T.U. The volumes provide information on the planning, construction and maintenance of a telephone network, which will be of considerable interest to telephone engineers, as a comprehensive coverage of the problems of running a telephone service is provided in a manner which is not usually possible in published papers or text books. Arrangements have been made for copies of the two volumes to be supplied at a cost of £4 4s. on application to the Post Office Engineering Department, E2/5, 2–12 Gresham Street, London, E.C.2.

Institution of Post Office Electrical Engineers

Essay Competition 1966–67

The Council of the Institution is indebted to Mr. T. J. Rees, Chairman of the Judging Committee, for the following report on the essay winning the first prize in the 1966–67 Essay Competition.

Mr. R. Williamson, the author of the prize-winning essay entitled "Design of Condenser Microphones—Some Practical and Theoretical Problems," has produced a well-balanced treatment of his selected subject, making liberal use of illustrations, circuit diagrams and graphs in explanation of the text. The overall effect is of an easily-readable essay, but of more importance is the fact that the essay is easily understandable by the amateur high-fidelity enthusiast with that degree of technical knowledge not uncommon amongst such people.

Mr. Williamson identifies himself as an amateur hi-fi enthusiast with limited financial resources and a desire for the best-available equipment. Having decided that the capacitor microphone was the best possible but well beyond the reach of his pocket, he set out to make one. The arrival at this decision was the easiest part of the whole process; the difficulties followed.

To embark upon such a project, the essential first step was to obtain a technical appreciation of the modus operandi and to become familiar with the basic design features of the capacitor microphone. This, the author claims, was not as easy as it sounded, because their design and construction had been, for some years, a German monopoly.

The essay takes the reader through the process of acquiring the desired amount of expertise, and provides technical information to assist in its assimilation. The difficulties in the actual construction, the pitfalls for the unwary and the ultimate successful outcome of the undertaking are described in sufficient detail to be of considerable assistance to any other "do-it-yourself" enthusiast who wishes to try his hand at a similar enterprise.

The essay (and other prize-winning essays), which will be kept in the Institution Central Library and which will be available to borrowers, can be thoroughly recommended to both the hi-fi enthusiast who feels inclined to try and emulate the author, and to anyone else who would merely like to know more about the intricacies of the capacitor microphone.

Essay Competition 1967–68

To further interest in the performance of engineering duties and to encourage the expression of thought given to day-to-day departmental activities, the Council of the Institution of Post Office Electrical Engineers offers five prizes, a first prize of six guineas and four prizes of three guineas, for the five most meritorious essays submitted by Post Office engineers below the rank of Inspector. In addition to the five prizes, the Council awards five certificates of merit. Awards of prizes and certificates made by the Institution are recorded on the staff dockets of the recipients.

An essay submitted for consideration of an award in the essay competition and also submitted in connexion with the Associate Section I.P.O.E.E. prizes will not be eligible to receive both awards.

In judging the merits of an essay, consideration will be given to clearness of expression, correct use of words, neatness and arrangement, and, although technical accuracy is essential, a high technical standard is not absolutely necessary to qualify for an award. The Council hopes that this assurance will encourage a larger number to enter. Marks will be awarded for originality of essays submitted.

Copies of previous prize-winning essays have been bound and placed in the Institution Central Library. Members of the Associate Section can borrow these copies from the Librarian, I.P.O.E.E., G.P.O., 2–12 Gresham Street, London, E.C.2.

Competitors may choose any subject relevant to current telephone, telegraph or radio practice. Foolscap or quarto paper should be used, and the essay should be between 2,000 and 5,000 words. An inch margin should be left on each page. A certificate is required to be given by each competitor, at the end of the essay, in the following terms:

"In forwarding the foregoing essay of..................words, I certify that the work is my own unaided effort both in regard to composition and drawing."

Name (in block capitals) ....

Signature ....

Rank ....

Departmental Address ....

Date ....

The essays must reach

The Secretary,
The Institution of Post Office Electrical Engineers,
G.P.O.,
2–12 Gresham Street,
London, E.C.2,

by 15 January 1968.

The Council reserves the right to refrain from awarding the full number of prizes and certificates if in its opinion the essays submitted do not attain a sufficiently high standard.

Institution Field Medal Awards, 1966–67 Session

The July 1967 issue of the Journal gave details of the medals awarded for the best papers read at meetings of the Institution in field subjects primarily of Regional interest.

The Council of the Institution is indebted to Mr. T. Kilvington, Chairman of the Papers Selection Committee of Council, for the following prècis of the medal-winning papers.

"Incentive Schemes in Industry" by J. D. Hitchcock

This paper is an introduction to the controversial subject of payment by results. The author begins by giving a brief history of incentives from the ancient world, through the cottage industry period of the Middle Ages, to the sophisticated schemes of Taylor, Halsey and Rowan in the late nineteenth century.

The author's main argument is that properly-applied incentive schemes increase productivity, raise the standard of living, relieve boredom and give people something to aim for. They motivate management as well as staff, and encourage all to eliminate inefficiency and bottlenecks.

Incentive schemes and their advantages and disadvantages are then compared. Simple piecework, for example, puts the emphasis on quantity of production, and may lead to quality decline unless proper checks are made. Task and bonus schemes are dealt with, followed by long-term systems based on profit-sharing and co-partnerships. Merit rating, well known to Civil Servants as part of the appraisement system, is used as a basis for incentive payments in some industries; but the author does not recommend it.

Successful introduction of an incentive scheme depends on a high degree of mutual trust between management and staff. Thorough staff negotiation must be preceded by work study to set standard time and to determine rates. Once set, these must not be lightly changed.

Three examples are given on incentive schemes used in certain industries which have been chosen because of their similarity to the Post Office.

The task bonus system in use by the Eastern Gas Board is described in some detail. A standard minute value has been calculated for each task performed by Gas Board staff, and they are paid extra for the time saved in the completion of each task. Its effect has been a remarkable increase in productivity. London Transport and certain cable contractors also run incentive schemes.

The author concludes his paper by suggesting that there is a case for payment by results for staff employed on Post Office engineering work. He describes a system that could be adapted to U.C.C. or, better still, to the C.S. costing scheme for installation work. Such a scheme would increase productivity, reduce overtime and ease recruitment difficulties in areas where there is competition for staff.

"Local-Line Planning for Service and Satisfaction" by R. Corbishley, C.Eng., M.I.E.E.

The White Paper of November 1963 set a target of March 1966 for the elimination of the telephone waiting list. Shortly afterwards an unprecedented demand for telephone service developed and placed enormous strains on both line-plant and equipment resources. Although service on demand was not in fact achieved, this was due to equipment shortages, and, by March 1966, line plant had ceased to be a significant factor in causing long delays in the provision of telephone service.

Against this background the author has shown:

(*a*) the size of the task nationally and in his own area,

(*b*) the methods employed to achieve results, firstly by means of a crash program of small simple schemes to provide plant quickly, followed by more normal methods streamlined to take into account local conditions, and

(*c*) the contribution made by new methods and materials in meeting the high demand, particularly the new polythene-sheathed cables and the reorganization of the Works Division into specialized parties for rodding, cabling, jointing, poling and wiring.

At the same time the extension of S.T.D. and I.S.D. have made it more than ever essential to improve the quality of service. The contribution that the external network is making towards this end by means of new types of cable, gas pressurization and good construction practices, particularly on new housing estates, have been covered.

While giving service on demand, the need to keep costs down has not been overlooked. The places where substantial savings can be made have been examined. They are

(*a*) long-length cabling,

(*b*) the use of lighter-gauge conductors, including the new $2\frac{1}{2}$ lb/mile cables, and

(*c*) modification of exchanges to higher signalling limits to enable line-plant savings to be made, and, where this is not possible, selective allocation of the modern equipment to serve the longer lines.

Finally, the author takes a quick look into the future to see the changes likely to be made if the provision of a quick and reliable service to the customer is to be continued.

"Efficiency in Motor-Transport Servicing" by H. A. Byatt

It is the author's view that, for reasons of safety, to honour statutory regulations and for prestige, Post Office vehicles must be maintained to high mechanical and visual standards. During the past two decades many improvements have been made by vehicle manufacturers in vehicle design and construction which have resulted in greater reliability and life of the motive units. This has changed the emphasis of vehicle maintenance from periodic overhauls suited to the earlier designs, to a system of graduated servicing based on vehicle life milage. Also, because of vehicle design and unsuitable accommodation at outstations, maintenance of vehicles at a properly-equipped servicing point has become essential. Furthermore, in the last 5 years a policy of purchasing vehicles by competitive tender coupled with a new replacement policy considerably reduces the time the Post Office holds the vehicles from new.

These factors dictate that changes should be made in the existing pattern of vehicle maintenance, and with this in mind an experimental system was introduced in the Midland Region on 1 April 1965.

The author explains the experiment carried out in the Midland Region. The essential features are a safety service every 1,000 miles and a system of graduated services, called major services, every 3,000 miles, the cycle being completed every 12,000 miles. The S1 safety service ensures that vehicles will be safe on the road, and also verifies that they will have a satisfactory fuel consumption if used under normal con-

(*continued on page 238*)

Regional Notes

South Western Region

FOWEY–POLRUAN SUBMARINE CABLE

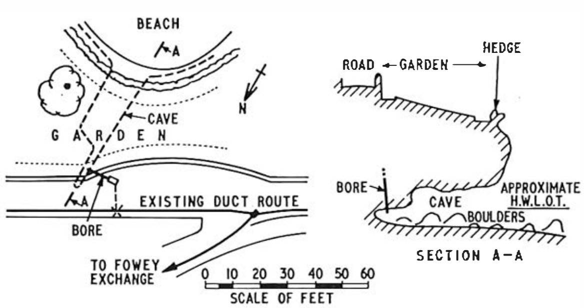
The projected replacement of the Fowey–Polruan junction cable gave the opportunity of seeking a shorter route for the new cable, as, apart from the obvious economies, the transmission loss on the existing route was outside limits.

A reasonable landing place for the submarine section was found at Polruan, adjacent to the Castle ruin, but no suitable beach existed on the Fowey side. It was noticed, however, that behind a small beach near the Fowey Hotel a cave ran in towards the Esplanade, as shown in the photograph, and it was decided to attempt to drill down from the road into the cave and route the cable via the bore hole.

THE CAVE AT FOWEY

The survey for the drilling was not without interest. A bulging cliff face precluded the direct dropping of a plumb, so a bipod was constructed out over the cliff face to carry the plumb line. Compass bearings were then taken of the plumb line from the cave and from the road above.

The survey showed that about 2 feet of the cave end was under the road, at a depth to the cave roof of 45 feet, as shown in the sketches.



THE BORE-HOLE FOR THE FOWEY–POLRUAN CABLE

There was a convenient position for the joint box in a passing bay at the cliff top, and, a suitable point for the cable entry into the cave roof having been chosen, it was calculated that drilling at an angle of 6°10′ to the vertical on a bearing of 90° (mag) was required. A Cornish firm of well borers agreed to drill the hole, provided that the lining up of the drill was done by P.O. staff.

Drilling through the 45 feet of rock took about 5 hours, the drill penetrating the cave roof within 1ft of the target. Samples of the debris at various depths were taken for the local surveyor. When the drill was finally withdrawn a chain was pulled up after it and left in situ to keep the bore clear.

For the laying of the cable by Submarine Branch, the local dredger was hired, a cable tank being constructed at deck level. Laying, from Polruan to Fowey, was without incident despite an increasing southerly wind. The Fowey end was manhandled ashore to the cave—a very wet business.

A special swivel had been previously made and welded to the Fowey end of the cable armouring. This swivel had a larger diameter than the cable, to clear the bore of any accumulated debris without passing any strain to the cable.

The bore-hole chain was attached to the swivel and the cable raised, without incident, by a pole jack. Finally, the cable was secured by turning back the armouring wires and securing them round a pudding ring which rests on the bottom of the box.

Compared with the old cable route, the new route is half a mile shorter, the submarine section being 200 yards less.

J.L.E.

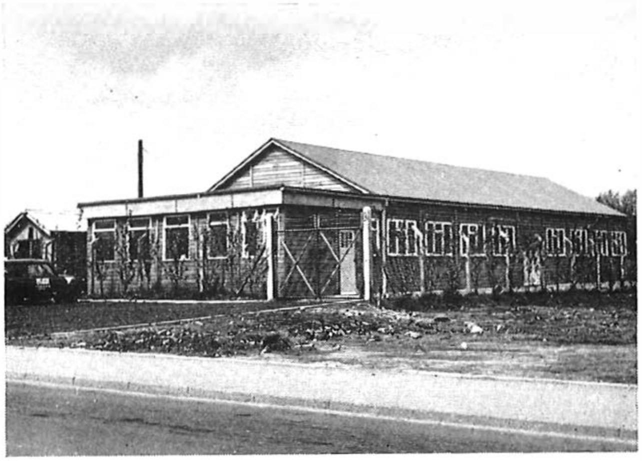
North Western Region

THE RELIEF OF SKELMERSDALE

Planning of a new town and integration of a six-fold increase in telephone lines is bound to be fraught with difficulties. When, during the period between "old manual" and "new auto-manual" exchanges, abnormal expansion of the telephone network hits the Area, the difficulties tend to increase. Skelmersdale new town was originally planned to be served by mobile exchanges on a temporary basis, until the new auto-manual exchange could be built and brought into service. However, the sudden expansion, and the fact that the majority of the new lines were being taken up by industrial organizations, rendered the use of mobile N.D. exchanges (M.N.D.X.s) inadequate. A revision of the forecast figures required the size of the new exchange to be almost doubled, and indicated that eight M.N.D.X.s would be needed to provide the multiple required by 1969, the due date for the new exchange. It was soon found that even eight mobile exchanges, although providing sufficient multiple, could not handle the high calling rate of the industrial organizations; in fact, each van in use was showing on overload with only 200 lines connected. Some of the final-selector groups also had to be augmented to cater for the high incoming-call rate.

Various relief expedients were considered, those of a temporary nature being adopted, where possible, to relieve the traffic-handling difficulties. In October of 1965 agreement was finally reached on the possibility of providing a temporary 2,000-line non-director exchange by local labour. The majority of the equipment for this was available on the Surplus Equipment Register, the remainder coming from temporary extensions within the Area which were due for early replacement by contract extensions. Since over 50 per cent of the multiple was to be for 2–10 P.B.X. lines some new equipment was ordered on the December 1965 Stores Order.

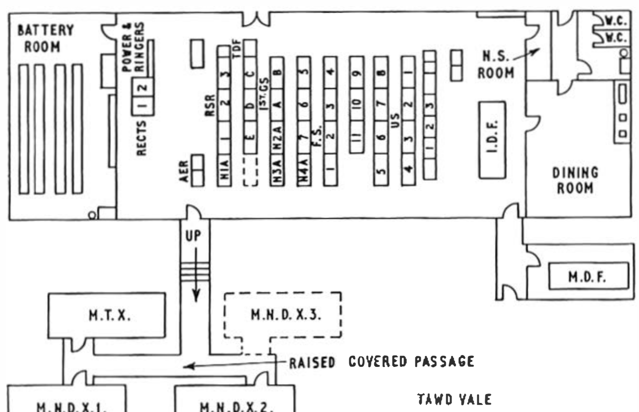
As no suitable building was available, a wooden building was proposed. Plans and specifications for building and site works were prepared, tenders obtained, contracts let, and site works completed by 31 March 1966. The building was ready for equipment by late May. This was almost a month later than anticipated due to unusual difficulties experienced by the builders. The building is of western redwood, lined with insulation board and inter-lined with glass fibre, the floor being of normal concrete and vinyl-tile finish. Heating is by thermostatically controlled tubular units supplemented by electrically heated water-filled radiators. Due to the delay in completion of the building, installation of the equipment commenced on the day following the laying of the vinyl tiles and it is notable that no troubles have arisen due to tiles lifting or expanding. The building is shown in the photograph.



TAWD VALE TEMPORARY N.D. EXCHANGE

The stability of the equipment racks is not dependent on the building in any way but is catered for by four 6 in. × 3 in. upright angle girders set into the concrete slab for this purpose. Their upper extremities are connected together by angle cross-members at 8 ft 6 in. and 10 ft 6 in. heights above floor level and, as two of the uprights coincide with the longitudinal centre-line of the I.D.F., rigidity of the system has been further improved by alternate use of 8 ft 6 in. and 10 ft 6 in. I.D.F. verticals. The footings of the I.D.F. are not set in concrete in the usual manner but are attached to the floor by lateral timbers and angle brackets; this should simplify recovery of the frame.

Overhead ironwork is standard and an overhead cable grid is employed. As the building has a pitched roof a catwalk comprising normal tongued and grooved floorboards nailed to 3 in. × 2 in. cross-members was made in 8 ft lengths, and laid down the centre of the grid. This produces almost the same scheme as for over-ceiling cabling, the cables passing under the catwalk in the space provided by the 3 in. battens. The battens are spaced so that they are bolted down to the supporting ironwork for safety reasons. Access to the cabling space is by means of a vertical ladder at the I.D.F. end of the building; thus, there was no need to leave cabling access holes in the grid.



PLAN OF THE EXCHANGE

Modification and overhaul of the various racks and items of equipment proceeded together with installation and cabling. The exchange was opened in December 1966.

As shown on the layout plan, the M.D.F. is contained in a separate hut. This is due to its original installation as a terminal point for the local distribution cables and tie-cables to the M.N.D.X.s in order to provide greater flexibility. There was nothing to be gained by moving the M.D.F. and re-terminating the local cables, as the 2,400-line multiple could be accommodated on the existing frame by integrating the work with the recovery of the M.N.D.X. tie-cables.

Little has been said about the many difficulties which arose during the installation of the apparatus, or of the many expedients adopted to overcome them, but with a good, loyal and determined staff anything is possible, as Tawd Vale (temporary) exchange proves. Credit is due to all those who have taken part in this unique venture.

A.F.

BURNLEY EXCHANGE RE-ARRANGEMENTS

In 1965 the pre-2,000 type non-director exchange at Burnley was replaced by a 4,000-type exchange in a building remote from the Head Post Office (H.P.O.) which housed the old exchange. The manual board in the H.P.O. was to be retained using the original equipment re-positioned and re-cabled in the old apparatus room to economize in space, thereby releasing a large area for postal purposes. With the introduction of S.T.D., the manual board was larger than necessary and arrangements were made to recover 11 positions, renumber the remaining positions, and recable the suite from the opposite end.

All of the work described is quite normal and was only complicated by the fact that the installation was kept in service throughout. The more unusual feature of the project was, however, in reducing the height of a suite of 22 manual board positions to conform with an existing modern suite. The whole of this operation was again carried out under operational conditions during normal working hours, the procedure being as follows.

(*i*) 1, 2 or 4 positions were taken out of service, depending on the type of construction.

(*ii*) All top woodwork from positions now out of service was removed.

(*iii*) As much iron work as possible from these positions was removed.

(*iv*) The stile bars were removed, leaving the jack field in position but unsupported.

(*v*) The stile bars and other iron work were then drilled and cut to size in a workshop set up in an adjacent room.

(*vi*) Packing pieces under the jack field were reduced in size to achieve the final height of the suite.

(*vii*) Stile bars and top iron work were then replaced and new board tops and cornices, supplied by the Factories Department, fitted.

(*viii*) Finally, the sliding doors from the backs of the boards were cut down and resprayed before being refitted.

This whole operation was carried out with a notable lack of interference to the staff or to the service, and with a considerable improvement in the appearance of the switchroom layout.

J.H.C.
K.J.S.

Associate Section Notes

London Centre

The annual conference was held at the Institution of Electrical Engineers on 24 May. Mr. E. Hoare presided and Mr. A. G. Welling was the Chairman. Most London Telephone Areas were represented at what proved to be a very satisfactory meeting.

During his Presidential address Mr. Hoare announced his retirement as our President. We shall be very sorry to lose Mr. Hoare as he has always shown a great interest in the affairs of the Associate Section. We wish to record our grateful thanks to him for all he has done during his period in office. At the time of writing the name of our new President is not yet known. Our congratulations to Mr. B. C. Low (City Area) and Mr. J. Skitmore (East Area) who each received this year's C. W. Brown Award. Congratulations also to South-West Telephone Area who were this year's winners of the inter-area quiz. This team will now meet Canterbury Centre later in the year. We wish to thank Telephone Managers of the various Telephone Areas for the use of official accommodation for all rounds of the quiz, the various catering bodies for providing refreshments, and the adjudicators and other officials for giving us their time at these meetings. Our thanks also to Mr. R. A. Hammond, our quiz organizer, without whose efforts at finding questions there would not be a quiz.

With annual leave in full swing the summer months are very quiet, although there has been the odd activity in some of the Telephone Areas.

The first meeting of the new session will be held at Fleet Building in September when the lecture will be on "Crossbar."

R.W.H.

Exeter Centre

The summer session started on 16 May with a visit to the B.M.C. car factory at Oxford. An early start was made, the members at Torquay leaving by coach at 6.0 a.m. and the remainder being picked up at Exeter at 7.0 a.m. During the conducted tour of the factory we were able to see the car body shells arriving at the factory at the beginning of the assembly line and follow their progress through the paint shops and on to the point where the assembled car was driven away. We were then taken to another part of the factory to see how the upholstery was made, and the ignition systems and dashboard instruments assembled, this work being carried out by disabled persons.

On 10 June a visit was made to the Decca School of Navigation at Brixham. At the school the Decca navigation system was explained, and later a practical demonstration was given on a trawler in Torbay.

The third visit was for members who live in the Torbay area, when, on 5 July, an evening was spent at the Newton Abbot bakery of Messrs. Hill, Palmer and Edwards. During the conducted tour members were able to see how bread and cakes were made. Our last visit of the summer was in September when members in the Exeter Telephone Area visited the Exeter bakery of Messrs. Hill, Palmer and Edwards.

Our winter program is being produced. In addition to visiting speakers we are hoping that some of our members will be giving short talks on their hobbies.

R.P.

Aberdeen Centre

The Centre brought the 1966–67 session to a close by holding its annual general meeting in the Imperial Hotel, Aberdeen, on 12 May 1967.

At the meeting office-bearers and committee members were elected, finance discussed and the 1967–68 program compiled. Our President, Mr. J. H. W. Sharp, Area Engineer, and Vice-President, Mr. H. A. McFarlane, were guests at the dinner which followed the a.g.m.

R.M.

Dundee Centre

Our annual general meeting was held on 22 June 1967 in the Royal Hotel, Union Street, Dundee, and was well supported. The following office-bearers and committee members were elected: *Chairman:* Mr. R. L. Topping; *Vice-Chairman:* Mr. R. C. Smith; *Secretary:* Mr. R. T. Lumsden; *Treasurer:* Mr. D. L. Millar; *Committee:* Messrs. Bannerman, Bell, Bunt, Burns, Hennesey, McNeil and Smith.

Mr. Topping in his report made sympathetic reference to the loss by death of two of our most staunch members, Jimmy Patrick from Perth and Howard Marshall of Dundee.

Some revolutionary suggestions for next session's program were made, so here's hoping we can carry out a few of them.

R.T.L.

Edinburgh Centre

Our program for the 1967–68 session has been arranged as follows:

September: "Microelectronics" by Dr. A. McNeill of Elliot Automation Co., Ltd.
November: A talk by Mr. W. E. Adams, Regional Engineer, on "Staff and Efficiency."
January: A talk on "Cable Pressurization," by Mr. D. R. Leask, Area Engineer.
A talk on "Pulse Code Modulation," by Mr. A. Sandison, Regional Headquarters.

Visits have been arranged to Ind Coope Co., Ltd., of Alloa—Skol Brewery, the Generating Station at Kincardine, S.T.V. Studios, Theatre Royal, Glasgow, and Hewlitt Packard Co., Ltd., South Queensferry. It is hoped that the meetings and visits will be of sufficient interest to attract an increase in the number of members attending.

G.A.K.R

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS (*Continued from page* 235)

ditions. This service is carried out by a workshop supervising grade. Major services provide a system of progressive preventive maintenance aimed at keeping the efficiency and appearance of vehicles up to a satisfactory standard, replacing the working units only when necessary, and, wherever possible, making major units last the life of the vehicle.

The programming of work on a mileage basis has been accomplished by rotation of postal vehicles and plotting the mileage basis of engineering vehicles.

To enable the S1 safety service to be carried out quickly and efficiently, special service bays have been set up in each workshop, fully equipped to check the road worthiness of a vehicle by using special instruments and gauges. Another feature of the maintenance bay is the mechanized oil-changing equipment, developed by the Midland Region, which enables oil to be changed in a matter of 2 minutes. This has converted a dirty and disagreeable task into a simple and clean job. The milage run by a vehicle between each greasing has also been extended to 3,000 miles.

Finally, the author stresses how important it is in any system of vehicle maintenance, to obtain close driver-mechanic liaison and co-operation.

Staff Changes

Promotions

Senior Executive Engineer to Assistant Staff Engineer

Name	Region, etc.	Date
Castellano, E. J.	Eng. Dept.	10.4.67
Lillie, S.	Eng. Dept.	8.5.67
Bubb, E. L.	Eng. Dept.	22.5.67
Walters, J. R.	Eng. Dept.	15.6.67

Executive Engineer to Area Engineer

Name	Region, etc.	Date
Iles, A. R.	E. Reg.	28.4.67
Varney, R. G. H.	Mid. Reg. to E. Reg.	31.5.67
Jelfrics, G. L.	E. Reg.	31.5.67
Wood, H. J.	N.W. Reg.	8.5.67
Cocking, R.	N.E. Reg. to N.W. Reg.	1.6.67
Cooper, W. J.	E.T.E. to L.T. Reg.	12.6.67
Benford, H.	Mid. Reg.	2.6.67

Executive Engineer to Senior Executive Engineer

Name	Region, etc.	Date
Rycroft, J.	N.E. Reg. to Scot.	10.4.67
Cheeseman, D. S.	Eng. Dept.	20.4.67
Button, R. W.	Eng. Dept.	10.4.67
Allan, T.	Eng. Dept.	26.4.67
Blakey, H.	Eng. Dept.	26.4.67
Tippler, J.	Eng. Dept.	28.4.67
Long, R. C.	Eng. Dept.	28.4.67
Davies, A. P.	Eng. Dept.	28.4.67
Ford, A. E.	Eng. Dept.	28.4.67
Burton, D. A.	E.T.E.	28.4.67
Allwood, M. E. (*In absentia*)	C.E.S.D. to Eng. Dept.	28.4.67
Larder, D. A. (*In absentia*)	Fiji to Eng. Dept.	28.4.67
Johnston, C.	Eng. Dept.	30.5.67
Whitecross, G. L.	Eng. Dept.	12.5.67
Ball, D.	Eng. Dept.	11.5.67
Mills, C. S.	Eng. Dept.	22.5.67
Walker, A. G.	Eng. Dept.	18.5.67
Ninnim, N. J. H.	Eng. Dept.	28.4.67
Gibbon, R. D.	L.P. Reg.	18.5.67
Busby, K. D.	L.T. Reg.	11.5.67
Watkins, A. H.	S.E. Reg.	6.3.67
Bishop, G.	Eng. Dept.	19.6.67
Shurrock, C. R. J.	Eng. Dept. to N.W. Reg.	19.6.67
Cooper, H. B.	Eng. Dept. to L.T. Reg.	19.6.67

Executive Engineer (Open Competition)

Name	Region, etc.	Date
Busby, J. L.	Eng. Dept.	4.4.67
Quinney, R. E.	Eng. Dept.	17.4.67
Russell, B. A.	Eng. Dept.	11.4.67
Carter, T. G.	Eng. Dept.	26.4.67
Burrows, K. G.	Eng. Dept.	3.7.67
Newman, W. J.	Eng. Dept.	18.5.67
Schickner, M. J.	Eng. Dept.	10.7.67

Assistant Executive Engineer to Executive Engineer

Name	Region, etc.	Date
Skinner, T. J.	S.E. Reg.	3.4.67
Wilson, D.	Scot.	18.4.67
Robinson, C. N.	N.E. Reg. to Mid. Reg.	17.4.67
Willitt, H. H.	W.B.C.	20.4.67
Alcock, V. G.	Mid. Reg.	17.4.67
Gange, W. L.	N.W. Reg.	20.4.67
Cross, P. C.	E. Reg.	24.4.67
Iliffe, D. A.	Mid. Reg.	17.4.67
Benefield, P. A.	S.E. Reg.	24.4.67
Boyd, S. A.	N.I. to N.W. Reg.	17.4.67
Hobbs, A. J.	L.T. Reg.	17.4.67
Izzard, A.	Eng. Dept.	17.4.67
Young, D.	Eng. Dept. to T.S.U.	17.4.67
Higgs, G. C. C.	Eng. Dept.	17.4.67
Christian, K. A.	Eng. Dept.	17.4.67
Bates, R. V.	Eng. Dept.	17.4.67
Loomes, B. J.	Eng. Dept.	17.4.67
Weller, D. C.	Eng. Dept.	17.4.67
Ryan, W. A.	Eng. Dept.	17.4.67
Thornton, T. C.	Eng. Dept.	17.4.67
Fenn, R. W.	E. Reg.	24.4.67
Goss, S. W.	E. Reg. to S.E. Reg.	24.4.67
Bartlett, V. W.	L.T. Reg.	17.4.67
Cooles, S. A.	L.T. Reg.	17.4.67
Aubertin, K. F.	L.T. Reg.	17.4.67
Witt, C. A.	L.T. Reg.	17.4.67
Walton, D. J.	C.E.S.D.	17.4.67
Cutmore, N.	Eng. Dept.	17.4.67
Carter, K. R.	Eng. Dept.	17.4.67
Wennell, J. L.	L.T. Reg.	17 4.67
Witt, G. E. J.	L.T. Reg.	17.4.67
Ayres, G. F.	L.T. Reg.	17.4.67
Norris, H. J.	Eng. Dept.	17.4.67
Carr, M. T. M.	L.T. Reg.	17.4.67
Pike, S. A. R.	L.T. Reg.	17.4.67
Hearn, J. R.	Eng. Dept.	17.4.67
Brading, E. T. A.	Eng. Dept.	17.4 67
Dowson, F. H.	Eng. Dept.	17.4.67
Pink, D. J.	S.E. Reg. to Eng. Dept.	17.4.67
Jones, I. O.	Eng. Dept.	17.4.67
Brenton, M. E.	Eng. Dept. to T.S.U.	17.4.67
Glover, L. O.	L.T. Reg.	17.4.67
Hornsby, R. J.	Mid. Reg.	17.4.67
Still, L. A. H.	Eng. Dept.	24.4.67

Promotions—*continued*

Name	Region, etc.	Date
Warburton, J. F.	E. Reg.	24.4.67
Walker, D. G.	Mid. Reg.	24.4.67
Hampson, K. C.	E. Reg. to Eng. Dept.	17.4.67
Hewett, J. W.	Eng. Dept.	17.4.67
Paine, N. J.	Eng. Dept.	17.4.67
Taylor, S. C.	Eng. Dept.	17.4.67
Hutchings, F. S. P.	Eng. Dept.	17.4.67
Lidbetter, A. J.	Eng. Dept.	17.4.67
Huggins, G.	Eng. Dept.	17.4.67
Davies, J. A.	Eng. Dept.	17.4.67
Allen, B. N. S.	Eng. Dept.	17.4.67
Brown, I. R.	E. Reg. to S.E. Reg.	15.5.67
Apperley, H. M.	S.W. Reg. to N.E. Reg.	22.5.67
Allan, J. M.	Scot.	1.5.67
Greer, W. A.	N.I.	1.6.67
Lindsay, M. J.	N.I.	1.6.67
Polglase, S. A.	E. Reg.	15.5.67
Kite, C. R. A.	Eng. Dept.	3.5.67
Medwell, J. D.	Eng. Dept.	15.5.67
Wyndham, R.	E. Reg.	30.5.67
Pethurst, I. A.	L.T. Reg.	1.5.67
Dieckmann, D. J.	Eng. Dept.	1.5.67
Amery, A. R.	Eng. Dept.	12.6.67
Hopkins, J.	L.T. Reg.	22.6.67
Gilks, G. F. L.	Eng. Dept. to L.T. Reg.	5.6.67
Melling, G.	Eng. Dept.	5.6.67
Bell, R. L.	S.W. Reg.	9.6.67
Piggott, I. D.	Mid. Reg.	5.6.67
Bist, A. G.	Eng. Dept.	12.6.67
Parker, A. E.	Eng. Dept.	5.6.67
Martin, R. W.	Eng. Dept.	12.6.67
Bain, A. J. R.	Eng. Dept.	5.6.67
Curtis, D.	Eng. Dept.	5.6.67
Perry, R. H. W.	Eng. Dept.	5.6.67
Whitehurch, H.	Eng. Dept.	5.6.67
Quested, W. G. M.	Eng. Dept.	5.6.67
Scott, D. D.	Eng. Dept.	5.6.67
Goss, C. E. G.	Eng. Dept.	5.6.67
Parkes, A. J.	Mid. Reg.	5.6.67
Hensby, W. W. S.	T.S.U.	5.6.67
Skinner, F. R.	Eng. Dept.	5.6.67
Bevan, J. S.	T.S.U.	5.6.67
Pattingdon, J.	L.T. Reg.	5.6.67
Hughes, R.	L.T. Reg.	5.6.67
Lowe, R. M.	Eng. Dept.	12.6.67
Bell, R. L.	Eng. Dept.	5.6.67
Lord, J. A.	Mid. Reg.	5.6.67
Hawkes, P.	N.W. Reg.	9.6.67
Johnson, G. A.	Mid. Reg.	5.6.67
Crocker, J. T.	S.E. Reg.	9.6.67
Bateson, W. R.	Mid. Reg.	5.6.67
Lee, P. J.	Eng. Dept.	14.6.67
Pacey, G. R.	Mid. Reg.	5.6.67
Humphries, M. A.	L.T. Reg.	5.6.67
Court, W.	Mid. Reg.	5.6.67
Roberts, D. G.	Eng. Dept.	5.6.67
Archer, L.	Eng. Dept.	5.6.67
House, B. H.	Eng. Dept.	5.6.67
Vogel, E. G.	Eng. Dept.	5.6.67
Stanton, S. C.	Eng. Dept.	5.6.67
Coleman, W. T.	Eng. Dept.	5.6.67
Franklin, A. K.	Eng. Dept.	12.6.67
Smith, T. R.	Mid. Reg.	5.6.67
Spears, R. G.	L.T. Reg.	5.6.67
Muir, W. W.	Scot.	9.6.67
Hadkiss, L. R.	Eng. Dept.	12.6.67
Rickarby, C. S.	Eng. Dept.	12.6.67
Wildblood, W. J.	Eng. Dept. to L.T. Reg.	5.6.67
Yates, T. C.	Eng. Dept.	5.6.67
Scanlan, W.	Eng. Dept.	5.6.67
Kitsell, J. H.	Eng. Dept.	5.6.67
Wall, H.	Eng. Dept.	5.6.67
Rand, I. C.	Eng. Dept.	12.6.67
Roberts, L. W.	Eng. Dept.	5.6.67
Hill, A. F.	L.P. Reg.	9.6.67
Bewick, R. T.	Eng. Dept.	5.6.67
Solaini, D. A.	L.T. Reg.	5.6.67
Lee, F. W.	Eng. Dept.	5.6.67
Simmons, P. D.	L.T. Reg.	5.6.67
Copping, P. J.	Eng. Dept.	5.6.67
Clifton, B. M.	N.E. Reg.	9.6.67
Briers, G. R.	Eng. Dept.	5.6.67
Gordon, J. A. E.	S.E. Reg. to Eng. Dept.	5.6.67
Smith, B.	T.S.U.	5.6.67
Hammett, A. J.	Eng. Dept.	5.6.67
Green, R. A.	Eng. Dept.	5.6.67
Gardner, D. L.	Eng. Dept.	12.6.67
Chamberlain, L. C.	Eng. Dept.	19.6.67
Jackson, M. J.	Eng. Dept.	5.6.67
Greenhill, J.	S.E. Reg. to Eng. Dept.	5.6.67
Tanner, R. K. R.	Eng. Dept.	5.6.67
Powell, D. J.	Eng. Dept.	5.6.67
Rothwell, F.	Eng. Dept.	5.6.67
Castle, W. C.	Eng. Dept.	5.6.67
Gipp, J. A. L.	Eng. Dept.	5.6.67
Ireland, W. A.	Eng. Dept.	5.6.67
Smith, J. F.	Eng. Dept.	5.6.67
Gilbey, A. W.	Eng. Dept.	5.6.67

Promotions—*continued*

Name	Region, etc.	Date
Wainwright, W. P.	Eng. Dept.	5.6.67
Kitt, M. J.	S.E. Reg.	16.6.67
Wellings, C. W.	Eng. Dept.	19.6.67

Inspector to Assistant Executive Engineer

Name	Region, etc.	Date
Nutt, J. A. J.	Scot.	10.5.67
Curtis, H. R. A.	S.E. Reg.	18.5.67
Price, A. F. H.	S.E. Reg.	18.5.67
Cornish, B. A.	S.E. Reg.	18.5.67
Cockbill, E. W.	Mid. Reg.	5.5.67
McCadden, W. H.	N.I.	22.5.67
Grundy, T. B.	Mid. Reg.	12 5.67
Preece, W. G.	L.T. Reg.	31.5.67

Technical Officer to Assistant Executive Engineer

Name	Region, etc.	Date
Webb, R. H.	N.W. Reg.	3.4.67
Cully, P. J.	N.W. Reg.	3.4.67
Darke, R. R.	S.W. Reg.	3.4.67
Glover, K. W.	N.W. Reg.	17.3.67
Cavies, S.	N.W. Reg.	17.3.67
Kingcombe, A. C.	S.W. Reg.	10.5.67
Donnelly, F. J.	N.W. Reg.	19.4.67
Brown, W.	N.W. Reg.	19.4.67
Kennedy, E. R.	N.W. Reg.	19.4.67
Hale, C. A.	N.W. Reg.	19.4.67
Kelly, T. J.	N.W. Reg.	19.4.67
Jones, W. T.	N.W. Reg.	19.4.67
Bassnett, B. A.	N.W. Reg.	19.4.67
Dalton, J. S.	N.W. Reg.	19.4.67
Goulden, C. J.	N.W. Reg.	27.4.67
Gennings, J.	N.W. Reg.	24.4.67
Plummer, G. W.	S.W. Reg.	17.4.67
Mettyear, R. V.	S.W. Reg.	17.4.67
Ryan, R. M.	Scot.	15.5.67
Haynes, J. N.	S.E. Reg.	18.5.67
Humphrey, E. D.	S.E. Reg.	18.5.67
Burchett, R.	S.E. Reg.	18.5.67
Brookes, R. A.	S.E. Reg.	22.5.67
Smith, R. W.	S.E. Reg.	18.5.67
White, J. F.	S.E. Reg.	18.5.67
Mason, R. A.	S.E. Reg.	18.5.67
Wilshire, E. A.	S.E. Reg.	18.5.67
Griffen, D. E.	S.E. Reg.	18.5.67
Lampard, B. P.	S.E. Reg.	18.5.67
Riley, J. W. G.	S.E. Reg.	18.5.67
White, B. L.	S.E. Reg.	31.5.67
Shuman, J.	S.E. Reg.	18.5.67
Craib, J. S.	Scot.	10.5.67
Harding, C. J.	W.B.C.	15.5.67
Wesson, T.	Mid. Reg.	5.5.67
Miller, N.	Mid. Reg.	5.5.67
Elford, S. R. V.	S.E. Reg.	18.5.67
Usher, J.	N.W. Reg.	23.5.67
Cowan, R.	N.I.	24.4.67
Bray, B. M.	L.T. Reg.	18.5.67
Woodbridge, J. H.	L.T. Reg.	18.5.67
Hammond, D.	L.T. Reg.	18.5.67
Rome, J. W.	L.T. Reg.	18.5.67
Beggs, R.	N.I.	15.5.67
Avent, E. C. D.	L.T. Reg.	31.5.67
Clark, D. G.	L.T. Reg.	31.5.67
Walter, D. V.	L.T. Reg.	31.5.67
Purkis, R. J.	L.T. Reg.	31.5.67
Littler, G.	N.W. Reg.	5.5.67

Draughtsman to Assistant Executive Engineer

Name	Region, etc.	Date
Scales, A. G.	S.E. Reg.	18.5.67
O'Doherty, P. J.	S.E. Reg.	18.5.67

Technical Officer to Inspector

Name	Region, etc.	Date
Elkin, F. H.	Mid. Reg.	25.5.67
Ryland, F. A.	Mid. Reg.	25.5.67
Elliott, R. G.	Mid. Reg.	25.5.67
Adams, A. G.	Mid. Reg.	25.5.67
Gibbs, J. R.	Mid. Reg.	25.5.67
Rogers, H. H.	Mid. Reg.	25.5.67
Williams, C.	Mid. Reg.	25.5.67
Cure, D. J.	Mid. Reg.	25.5.67
Bardler, A. H.	Mid. Reg.	25.5.67
Groom, A. W.	Mid. Reg.	25.5.67
Smith, J. R.	Mid. Reg.	25.5.67

Senior Technician to Inspector

Name	Region, etc.	Date
Hindman, W. H.	N.I.	1.5.67
Woods, W. H.	N.W. Reg.	23.5.67

Technician I to Inspector

Name	Region, etc.	Date
Grindlay, N.	W.B.C.	8.5.67
Gallagher, G. A.	N.W. Reg.	23.5.67

Senior Scientific Officer to Principal Scientific Officer

Name	Region, etc.	Date
Rollett, J. M.	Eng. Dept.	15.6.67
Merlo, D.	Eng. Dept.	15.6.67

Promotions—*continued*

Name	Region, etc.	Date
Experimental Officer to Senior Experimental Officer		
Elliott, C. R.	Eng. Dept.	27.6.67
Scientific Officer to Senior Scientific Officer		
Bond, D. J.	Eng. Dept.	18.5.67
Experimental Officer (Open Competition)		
Narayanan, M.	Eng. Dept.	1.6.67
Scientific Officer (Open Competition)		
Geary, D. A.	Eng. Dept.	28.4.67
Assistant (Scientific) (Open Competition)		
Fowler, K. R.	Eng. Dept.	20.6.67
Technical Assistant to Assistant Regional Motor Transport Officer		
Ridout, J. F.	London Reg.	5.4.67
Entwhistle, F. C.	N.W. Reg.	5.4.67
Technical Assistant to Motor Transport Officer III		
Hankin, J. B.	Eng. Dept.	5.4.67
Leading Draughtsman to Senior Draughtsman		
Harding, S. J.	Eng. Dept. to N.E. Reg.	17.4.67
Halls, P. S.	Eng. Dept.	13.4.67
Ilett, D. H.	Eng. Dept.	3.7.67
Draughtsman (Open Competition)		
Tillson, J. W.	Eng. Dept.	19.4.67
Reeve, P. W. R.	Eng. Dept.	5.5.67
Weavers, A. F.	Eng. Dept.	12.6.67
Executive Officer (Limited Competition)		
Roberts, H. W.	Eng. Dept.	4.4.67

Retirements and Resignations

Name	Region, etc.	Date
Assistant Staff Engineer		
Hall, A. W.	Eng. Dept.	30.4.67
Area Engineer		
Hobbs, H.	Mid. Reg.	13.4.67
Arnold, A. F.	W.B.C.	30.4.67
Wooding, W. J.	L.T. Reg.	31.5.67
Affleck, D. B.	Mid. Reg.	1.6.67
Senior Executive Engineer		
Lafosse, L. P.	Eng. Dept.	31.5.67
Executive Engineer		
Herbert, L. J.	L.T. Reg.	5.4.67
Barnett, F. P.	L.T. Reg.	8.4.67
Baynham, L. J.	Mid. Reg.	4.1.67
Turner, A. F.	L.T. Reg.	1.4.67
Robinson, M. E.	Eng. Dept.	2.5.67
Chapman, R. W.	L.T. Reg.	6 5 67
Wilkinson, W.	N.W. Reg.	15.5.67
Boyd, W. J.	N.I.	31.5.67
Cooper, E. B.	L.T. Reg.	31.5.67
Groome, J. S.	Scot.	22.5.67
Berry, J. C. (*Resigned*)	Eng. Dept.	12.5.67
Assistant Executive Engineer		
Gregory, W.	N.W. Reg.	30.4.67
Preston, R. L.	S.W. Reg.	10.5.67
Jackson, W. C.	S.E. Reg.	18.5.67
Waight, T. A.	L.T. Reg.	20.5.67
Prentice, J. A.	L.T. Reg.	24.5.67
Stratford, S.	L.P. Reg.	26 5.67
Adair, W. H.	N.I.	28.5.67
Stanley, E. A.	L.T. Reg.	30.5.67
Allan, R. A.	S.E. Reg.	31.5.67
Mack, G. L.	Eng. Dept.	31.5.67
Brown, L. M. (*Resigned*)	Eng. Dept.	31.5.67
Terrell, T. J. (*Resigned*)	Eng. Dept.	31.5.67
Inspector		
Hough, G.	N.W. Reg.	20.4.67
Assistant (Scientific)		
Redshaw, H. M. (Mrs.) (*Resigned*)	Eng. Dept.	16.6.67
Leading Draughtsman		
Winterborne, A. C.	Eng. Dept.	14.4.67

Transfers

Name	Region, etc.	Date
Assistant Staff Engineer		
Breary, D.	I.T.U. to Eng. Dept.	5.6.67
Senior Executive Engineer		
Blair, G. M.	Eng. Dept. to S.E. Reg.	30.5.67
Wheele, D. W. G.	Ministry of Transport to Eng. Dept.	1.5.67
Downing, S. A.	E. Reg. to Ghana	4.6.67
Executive Engineer		
Lough, J.	N.E. Reg. to N.W. Reg.	7.11.67
Morris, W. A.	Eng. Dept. to Patent Office, Board of Trade	16.5.67
Best, F. L.	Eng. Dept. to E. Reg.	12.6.67
Balls, R. W.	Eng. Dept. to E. Reg.	19.6.67
Brooks, M.	Eng. Dept. to Hong Kong	14.6.67
Hurcom, J. G.	Eng. Dept. to Sabah	8.7.67
Goymer, E. G.	Eng. Dept. to L.T. Reg.	1.6.67
Reid, D. F.	Eng. Dept. to N.E. Reg.	5.6.67
Hitchen, E. J. T.	S.E. Reg. to Met. Police	9.7.67
Assistant Executive Engineer		
Deacon, H. C.	L.T. Reg. to Eng. Dept.	8.5.67
Kirby, D. J.	L.T. Reg. to E. Reg.	15.5.67
Walker, R. W.	Eng. Dept. to Home Office	22.5.67
Taylor, C. H.	E. Reg. to S.E. Reg.	30.5.67
Draughtsman		
Bennett, G. W.	Eng. Dept. to E. Reg.	3.4.67
Curtis, V. D.	Eng. Dept. to L.T. Reg.	3.4.67
Suett, C. G.	Eng. Dept. to N.W. Reg.	5.6.67
Executive Officer		
Davies, J. H.	C.E.S.D. to Eng. Dept.	17.4.67

Deaths

Name	Region, etc.	Date
Executive Engineer		
Jennings, L. T.	S.W. Reg.	29.5.67
Assistant Executive Engineer		
Jones, R.	W.B.C.	5.5.67
Fairman, W. G.	E. Reg.	7.5.67

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Model Answer Books

Books of model answers to certain of the City and Guilds of London Institute examinations in telecommunications are published by the Board of Editors. Details of the books available are given at the end of the Supplement to the Journal.

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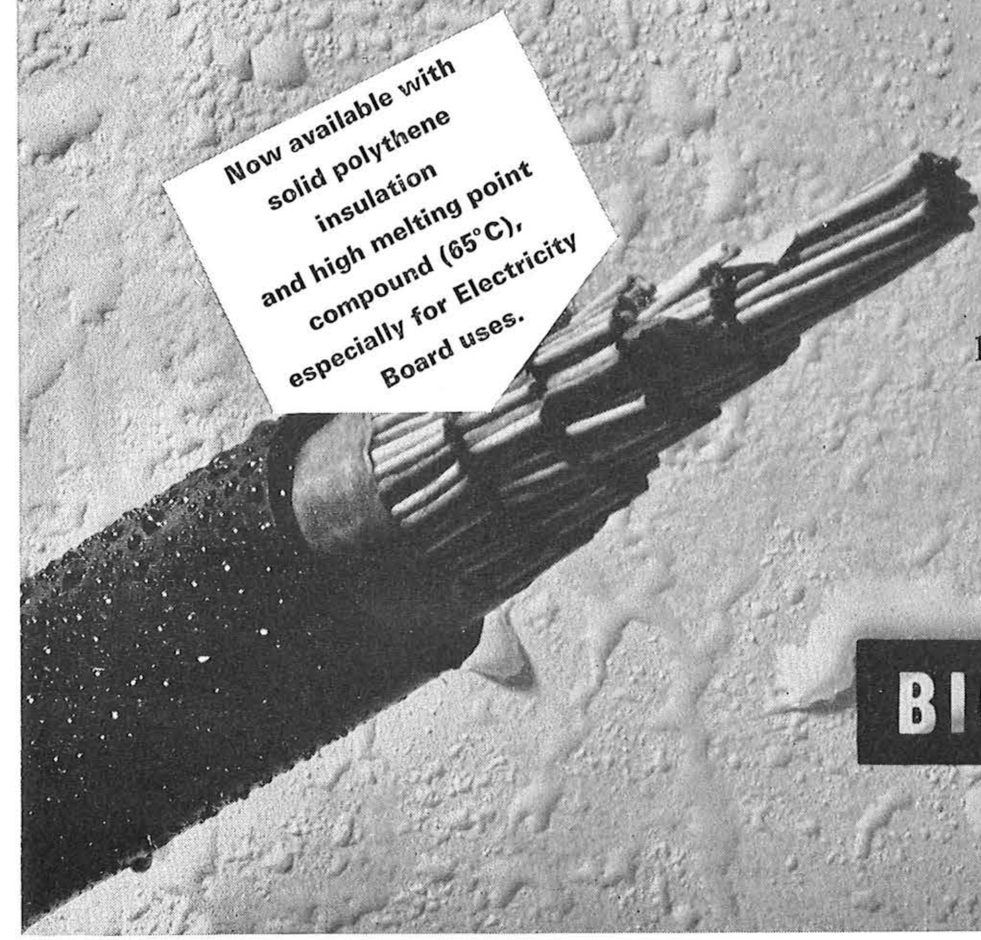

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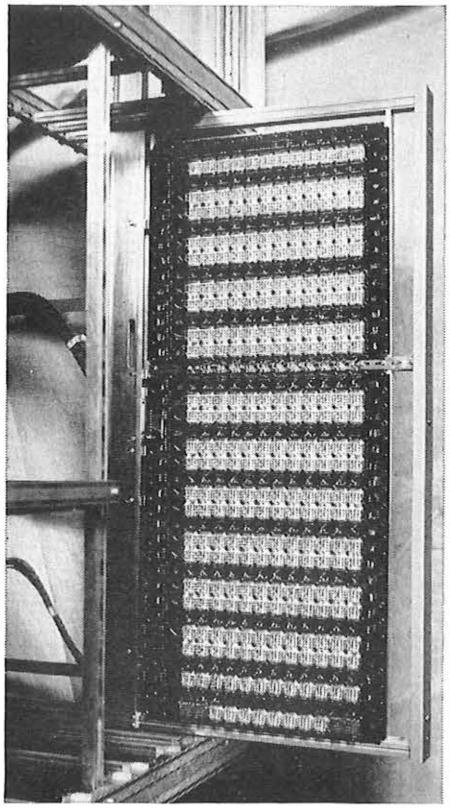
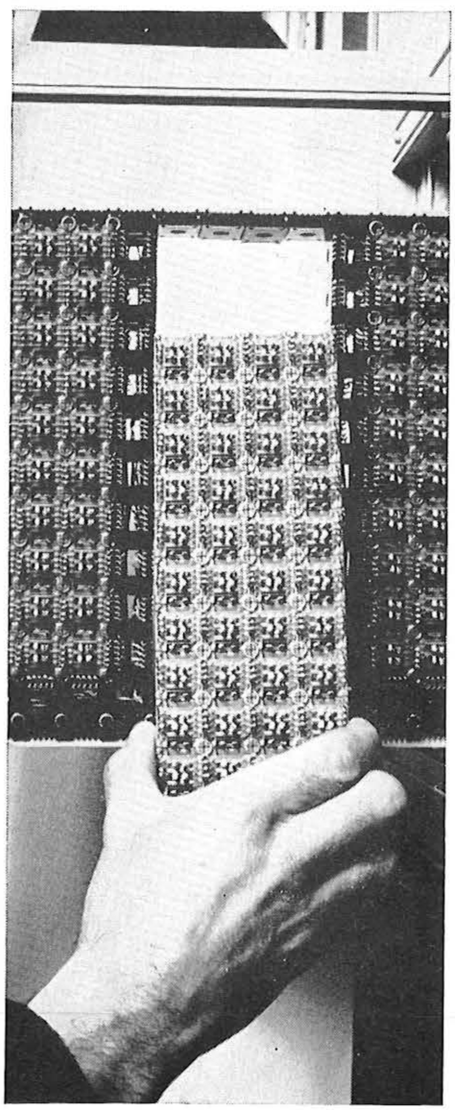




REX

THE REED ELECTRONIC EXCHANGE

No. 18 system

packs more lines into less space— AND LEAVES ROOM FOR UNLIMITED EXPANSION

REX in a nutshell

By providing electronic common control of reed relay spatial switching, the REX system offers an extremely compact and reliable solution to both the switching and control problems of modern exchange design. The REX exchange has been developed by AEI to integrate smoothly with existing automatic networks: its exceptional flexibility ensures full growth capacity for both services and traffic...

Wider range— more accessibility

An entirely new Reed & Electronic Modular Apparatus practice (REMA) has been designed by AEI engineers to provide completely compatible mounting of reed relays and electronic circuit components. Combined with a new sliding-frame mounting system, the REMA practice allows more than 20,000 lines of REX switching equipment to be accommodated in the space normally required by a 10,000 line electro-mechanical exchange. In existing buildings this means more space for future expansion: in new exchanges it makes possible great savings in construction and installation costs. And because the REX subscriber's line circuit can tolerate substantially wider line conditions, a REX exchange will serve an area much larger than that of a conventional exchange, with significant reductions in line plant investment.

Designed for expansion

The basic design allows for all future switching requirements, including abbreviated dialling and subscriber's automatic transfer, together with all current standard features such as data for automatic message accounting. A stored programme control is provided to expedite inclusion of these and any other special facilities that may be required during the life of the exchange with virtually no redundancy of initial apparatus.

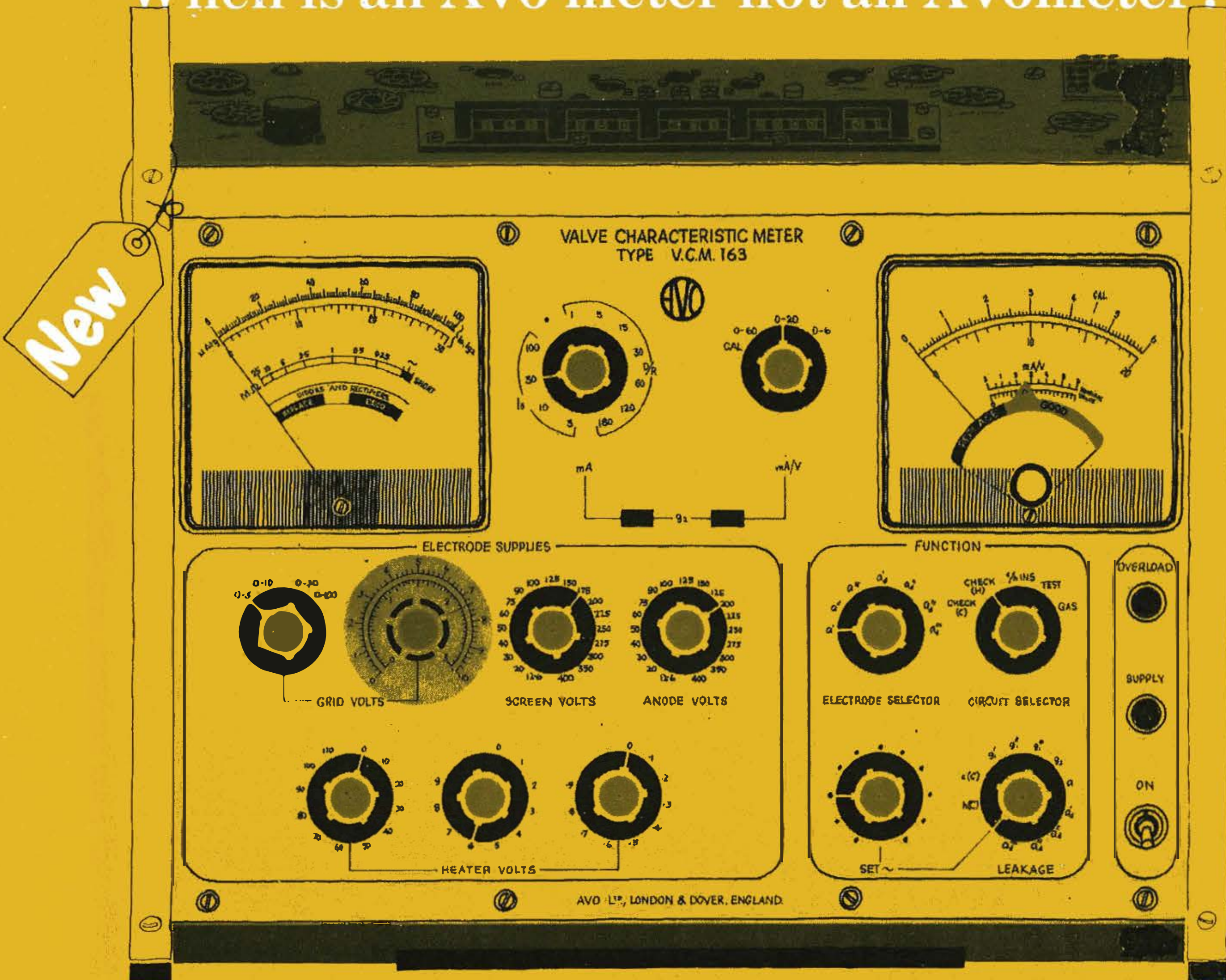
Minimum maintenance

The high-speed electronic control system is programmed to give complete automatic self-checking and self-reporting of fault conditions and at the same time, routes calls away from areas of faulty equipment. A 3,000 (ultimately 7,000) line prototype reed electronic exchange supplied to the BPO at Leighton Buzzard,* has been designed for completely unattended operation and reports all servicing requirements to a remote maintenance control centre.

Maximum service security has been ensured by exhaustive circuit design and testing during the development period and by replication of important items of equipment. The control area is sub-divided into independently switched functional units thus ensuring continued operation in the face of faults. Thanks to the REMA system every part of the REX exchange is accessible for inspection or servicing.

* *Developed in conjunction with the BPO under the auspices of the Joint Electronic Research Committee.*

When is an Avo meter not an Avometer?



When it tests nuvistors, compactrons & 13-pin valves

The new Avo VCM163 Valve Characteristic Meter is one of the most versatile valve testers ever developed. With facilities for testing valves with as many as 13 pin connections (and 2 top caps), plus recently introduced types such as nuvistors and compactrons, the VCM163 provides both rapid fault diagnosis and comprehensive static/dynamic characteristics data. Nevertheless, it is even simpler to use than previous models – no backing-off is required. A separate meter displays mutual conductance values continuously during testing, and there is pushbutton monitoring of screen parameters. The full range of h.t. voltage – 12.6V to 400V – can be applied to anode and screen, heater voltage is adjustable in 0.1V steps from 0 to 119.9 and grid voltage may be varied continuously from 0 to 100V (calibrated). Get complete information about the VCM163 from your local dealer or Avo Ltd, Avocet House, Dover, Kent. Telephone Dover 2626. Telex 96283.

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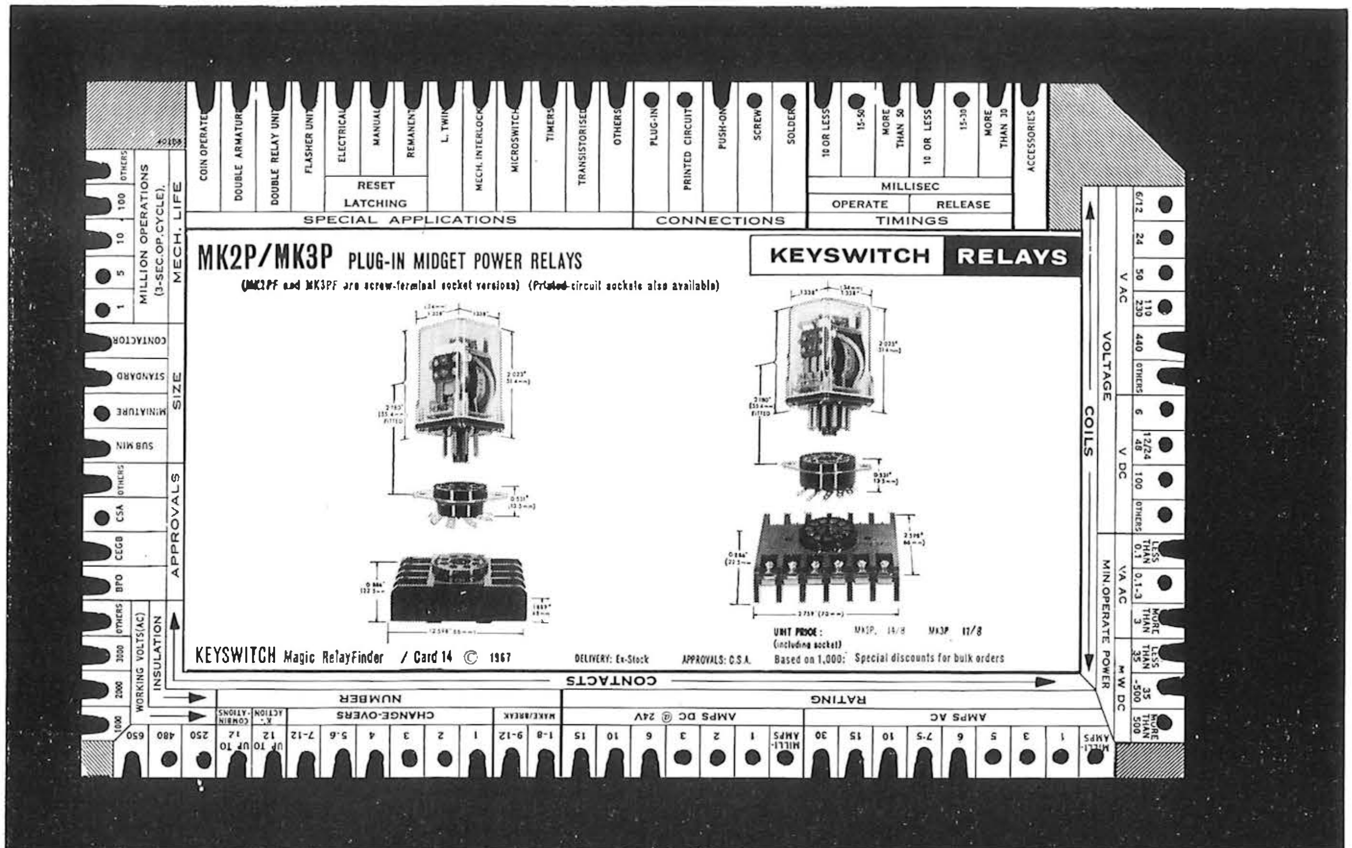

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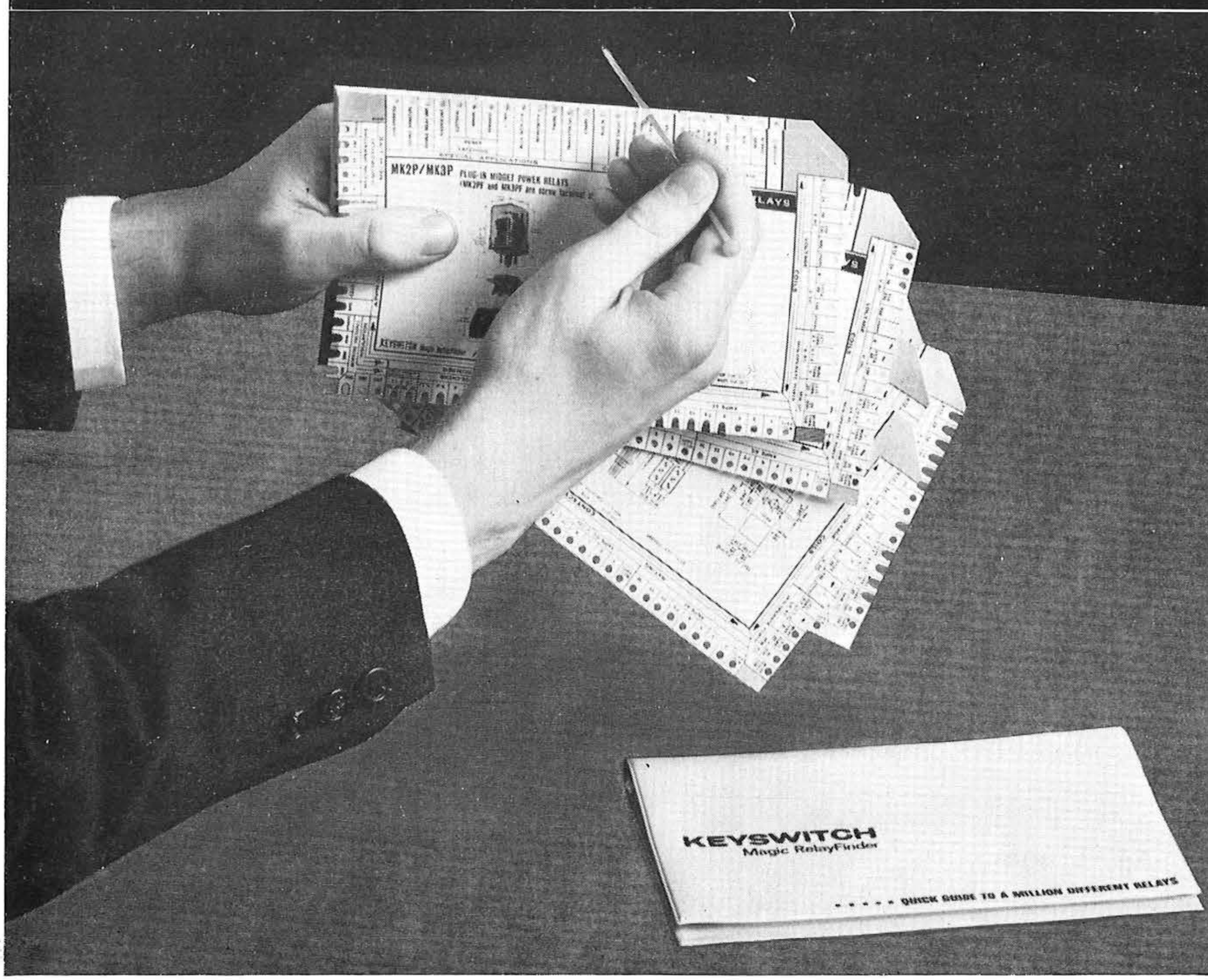

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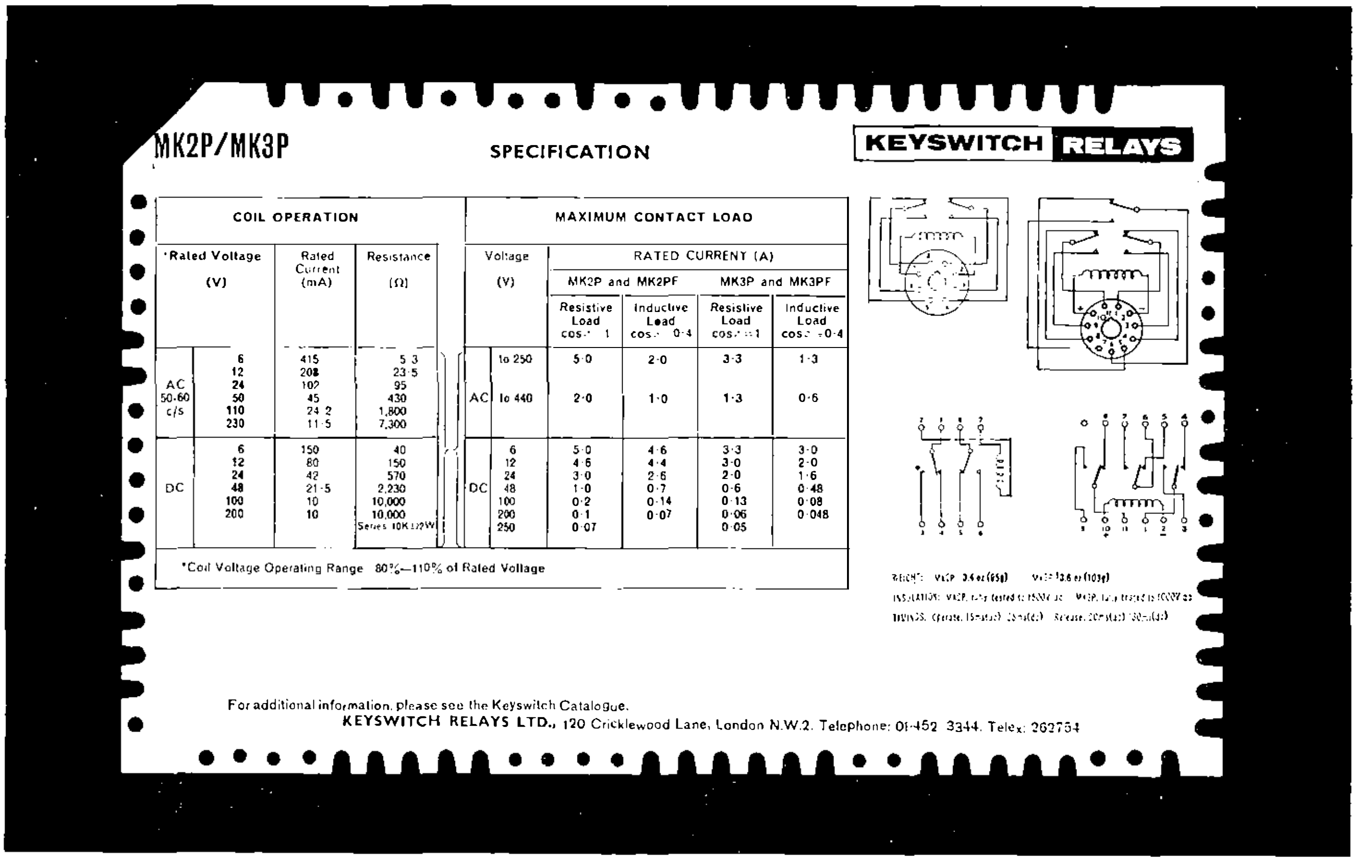

MK2P/MK3P SPECIFICATION KEYSWITCH RELAYS

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*Rated Voltage (V)		Rated Current (mA)	Resistance (Ω)	Voltage (V)		RATED CURRENT (A)			
						MK2P and MK2PF		MK3P and MK3PF	
						Resistive Load cos ϕ 1	Inductive Load cos ϕ 0·4	Resistive Load cos ϕ =1	Inductive Load cos ϕ =0·4
AC 50-60 c/s	6	415	5·3	AC	to 250	5·0	2·0	3·3	1·3
	12	208	23·5		to 440	2·0	1·0	1·3	0·6
	24	102	95						
	50	45	430						
	110	24·2	1,800						
	230	11·5	7,300						
DC	6	150	40	DC	6	5·0	4·6	3·3	3·0
	12	80	150		12	4·6	4·4	3·0	2·0
	24	42	570		24	3·0	2·6	2·0	1·6
	48	21·5	2,230		48	1·0	0·7	0·6	0·48
	100	10	10,000		100	0·2	0·14	0·13	0·08
	200	10	10,000 Series 10K 1/2W		200	0·1	0·07	0·06	0·048
					250	0·07		0·05	

*Coil Voltage Operating Range 80%—110% of Rated Voltage

For additional information, please see the Keyswitch Catalogue.
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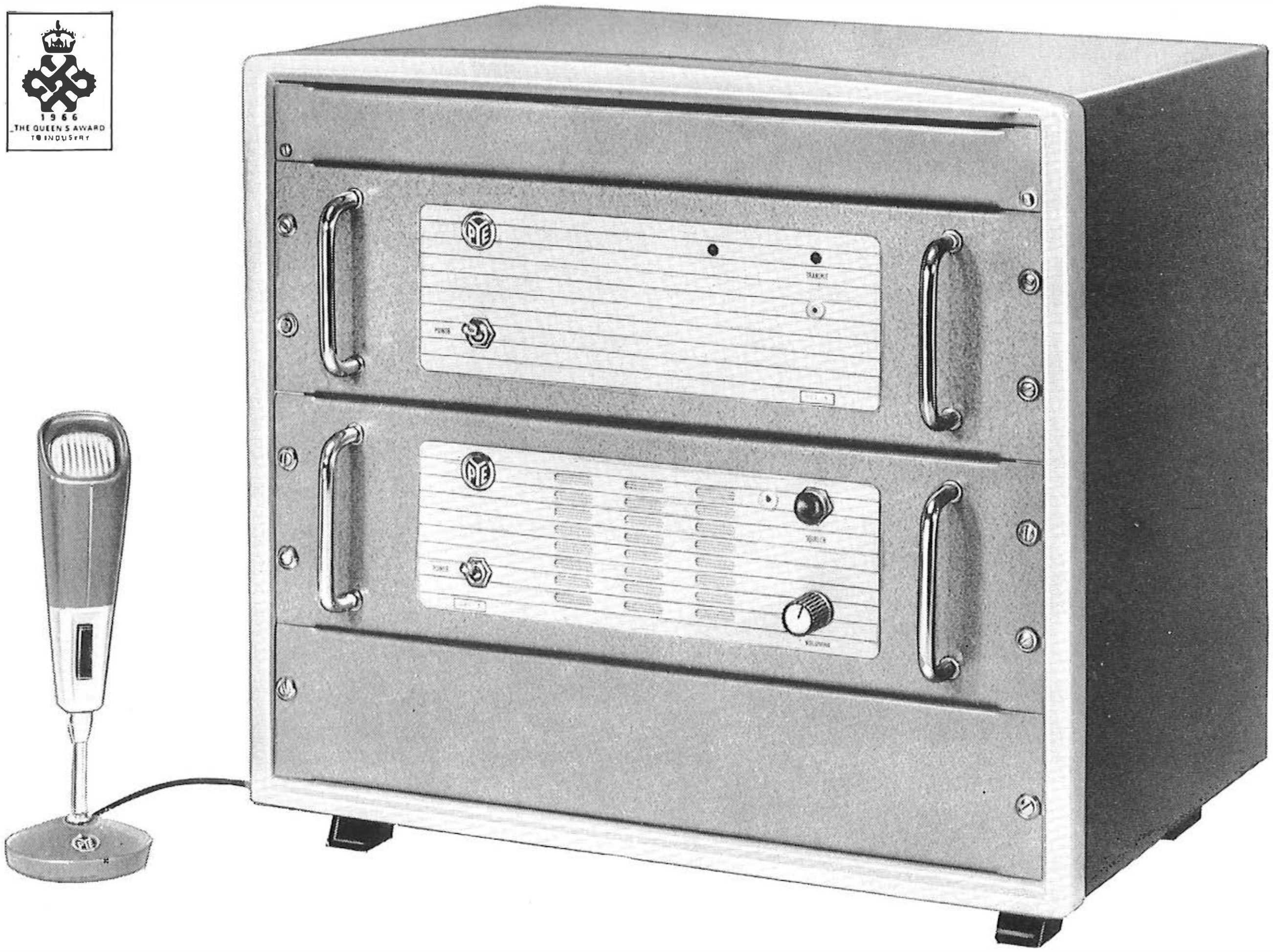

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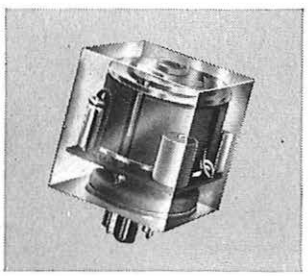

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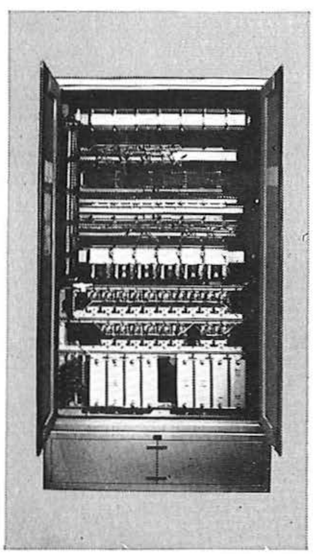

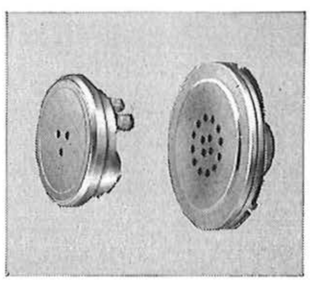

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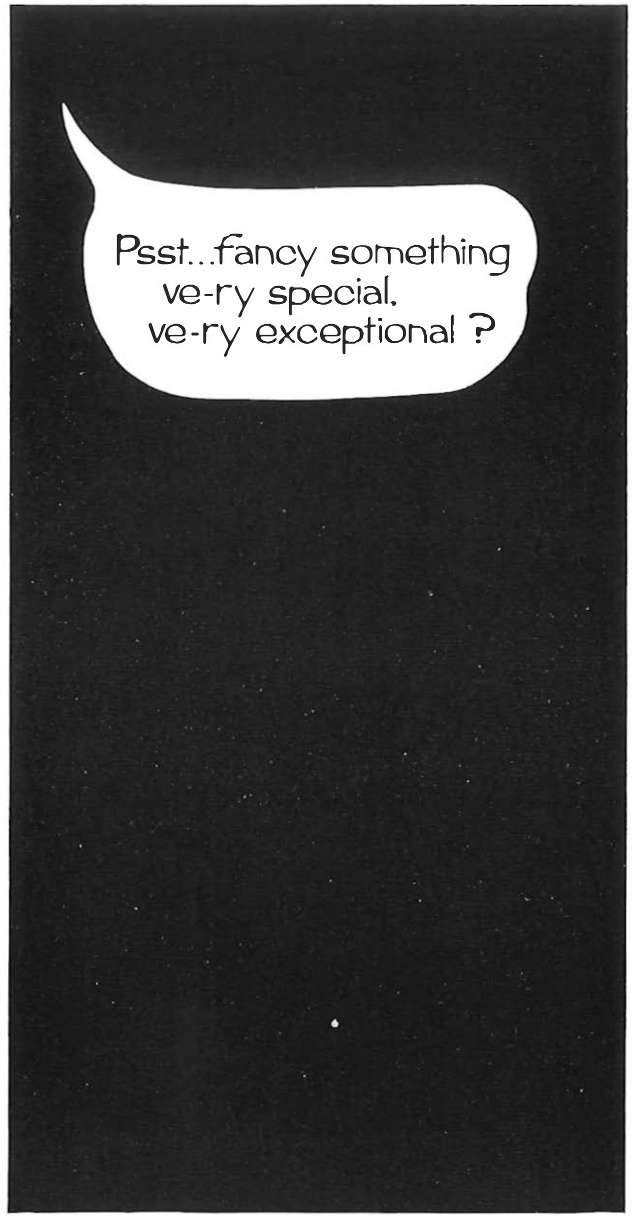

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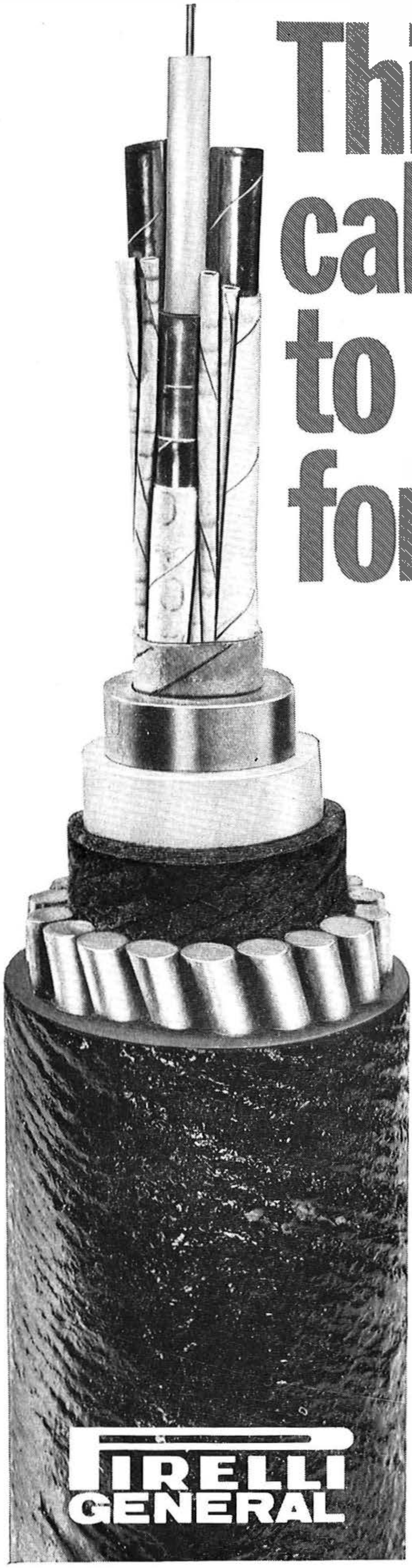
P8475

This coaxial cable has to be perfect for all locations



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Manufactured by Pirelli General, the first armoured miniature coaxial cable to be installed in Britain was recently laid on the bed of the River Tamar as part of the 80 mile telecommunications link between Plymouth-Truro-Penzance. Installation was by Pirelli Construction Company, except for the river crossing, carried out by the General Post Office.

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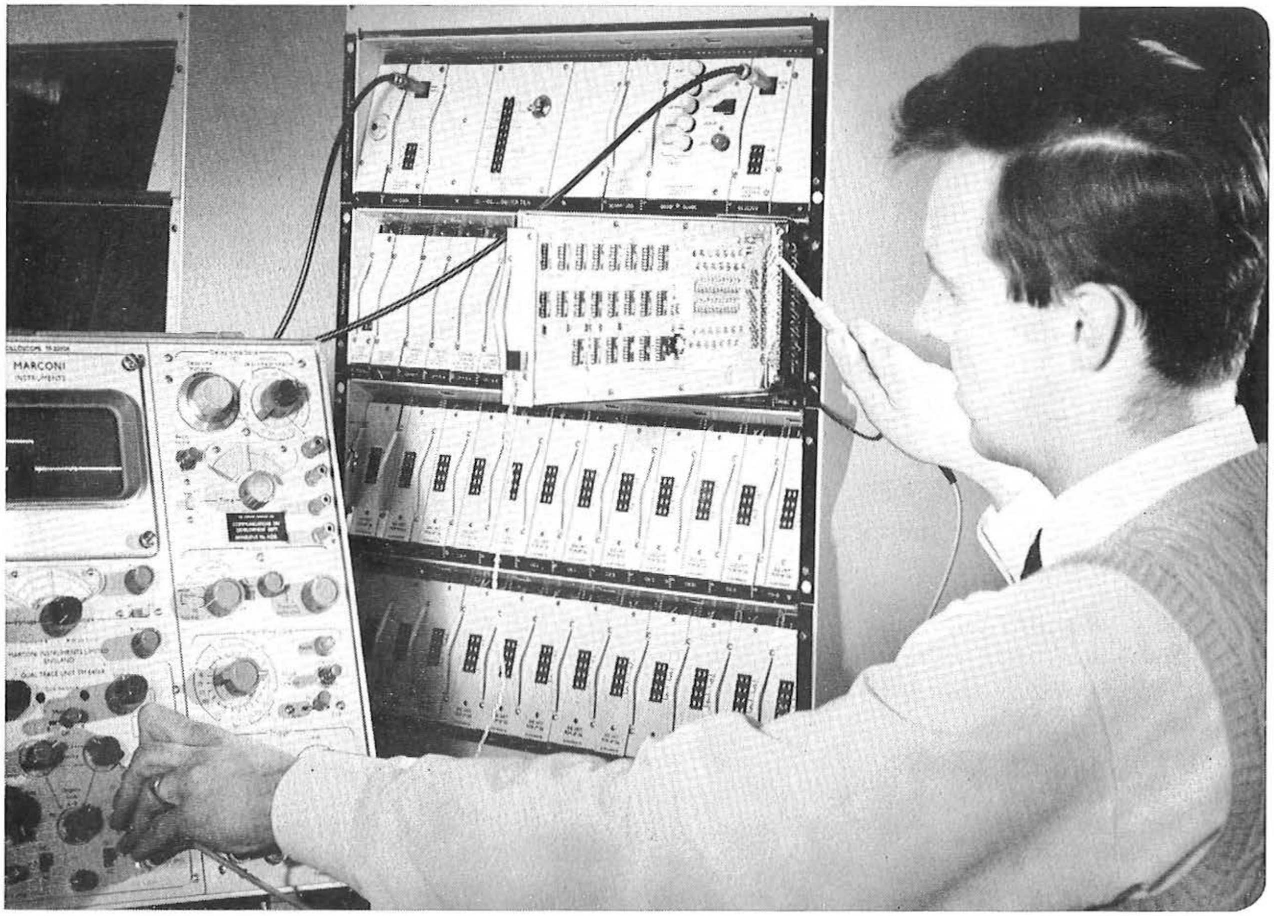

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communications systems

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'Five 24 channel terminals on a standard 9′ rack'

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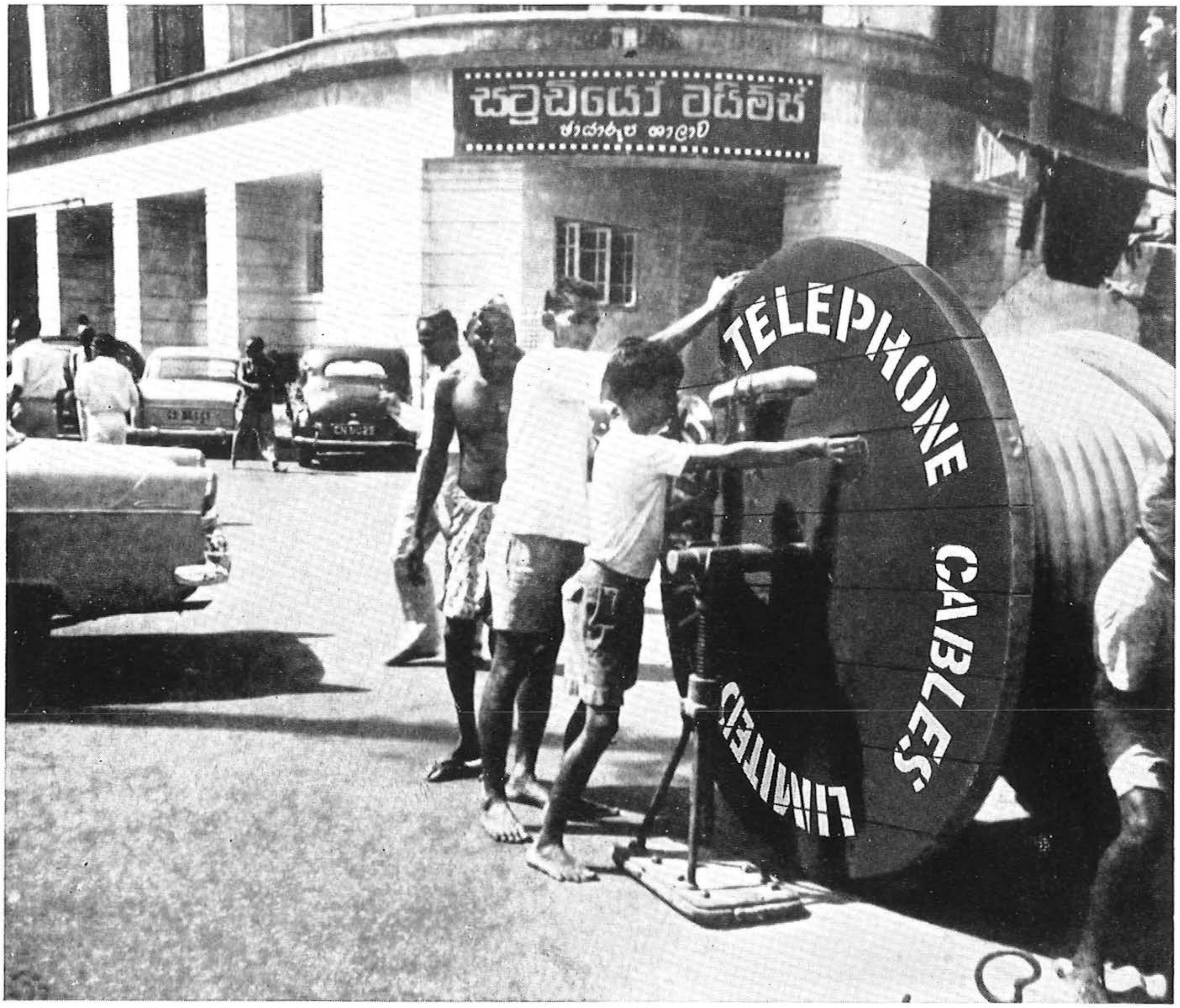

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STC Telecommunications Review

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Telecommunicati

Microwave System in Peru The 1100-mile (1800 km) microwave radio system now fully commissioned and in service in Peru is a good example of the "turnkey" capability of G.E.C. (Telecommunications) Ltd., since the company, as prime contractor, had overall responsibility for the entire project. This system which is the longest of its type in Latin America, uses 2000 MHz equipment.

Microwave System in Chile
The completely semiconductored microwave radio system being supplied by G.E.C. for the Northern Zone of Chile will stretch 1163 miles (1871 km). The main route, between Santiago and Arica, will be equipped with a system operating in the 2000 MHz frequency band, while the secondary network and spur routes will use systems operating at 7500 MHz., 2000 MHz and also 5 and 12-circuit systems in the VHF and lower UHF frequency bands.

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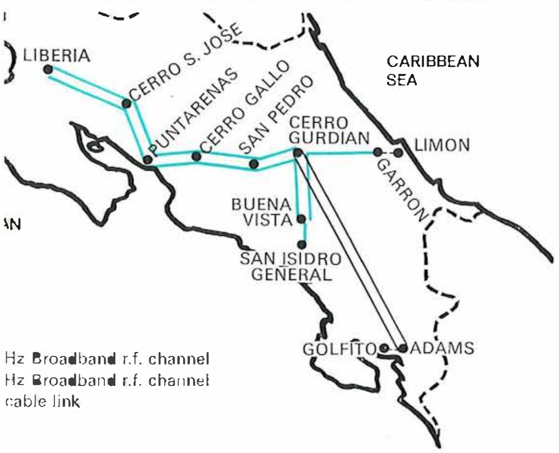
sets the pace in
ɔns progress in Latin America

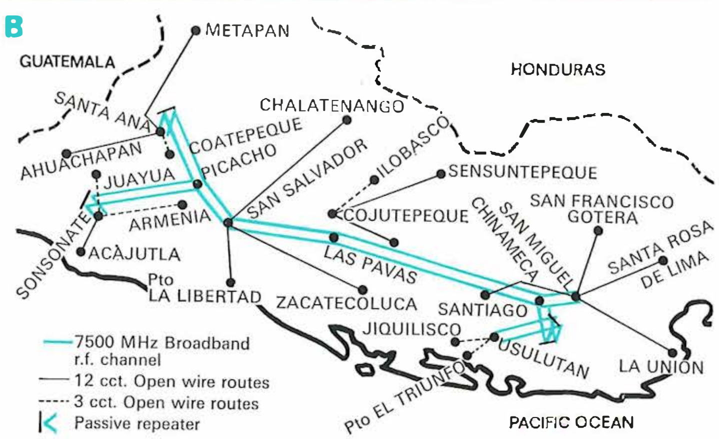
microwave radio communication networks by G.E.C. of England, including several featuring the ɛmiconductored 7500 MHz broadband radio equipment, are making a substantial contribution to ıications progress in Central and South America.

ıclude microwave radio systems for Costa Rica, El Salvador, Peru, and Chile. These networks, ferent types of terrain and a wide range of climatic conditions, demonstrate the versatility of G.E.C. systems in widely differing applications. They include an example of an installation for which ɔeen appointed as prime contractor on a "turnkey" basis.



System in Costa Rica

plying a nationwide microwave radio ık all the principal towns in Costa Rica. ıking Liberia, San José, San Isidro General, e being equipped with completely ɔred equipment operating at 7500 MHz with 300 speech circuits. On these sections of the ted channels will operate on the twin-path re very high system reliability. The complete ch also includes 960-circuit 6000 MHz ɪuipment for the more heavily loaded route o Gurdian and Adams, as well as cable links ɔonnexions between the radio stations and s, is being installed and commissioned



Microwave System in El Salvador

The microwave trunk network now in service in El Salvador was planned and installed by G.E.C. using 7500 MHz 300-speech circuit completely semiconductored equipment. The network interconnects regional centres throughout the country each of which have their own open-wire network connecting them to the smaller townships and villages. The contract for the open-wire equipment was also awarded to G.E.C. A feature of the 7500 MHz network is the use of passive repeaters to enable the radio equipment to be installed in easily accessible areas. This system also operates on a twin-path basis to provide frequency diversity.

Takes telecommunications into tomorrow

G.E.C. (Telecommunications) Ltd.
Telephone Works, Coventry,
England.

G.E.C. of England

brings latest techniques to 7500 MHz equipment

Specification summary

S.H.F. Semiconductored Broadband Radio Relay Equipment

Radio

Operating Frequencies:
7425 MHz to 7725 MHz

Transmitter Output:
200 m W

Receiver IF Bandwidth:
20 MHz

Receiver Noise Factor:
11 db maximum

IF Input/Output Impedances:
75 ohms unbalanced

Baseband

Capacity:
Up to 300 circuits

Input level:
—42 dbr
75 ohms unbalanced

Output Level:
—18 dbr
75 ohms unbalanced

Mean Deviation

300 circuits:
200 kHz

120 circuits:
280 kHz

Pre-emphasis

Over 120 circuits:
To C.C.I.R. Recommendation No. 275 (Geneva 1963)

120 circuits or less:
None required

Serviceband

Omnibus Engineer's Service Channel:
200 Hz to 3400 Hz

Calling on Service Channel:

Terminal to Repeater:
Loudspeaker

Repeater to Terminal:
Out-of-Band tone

Antenna System

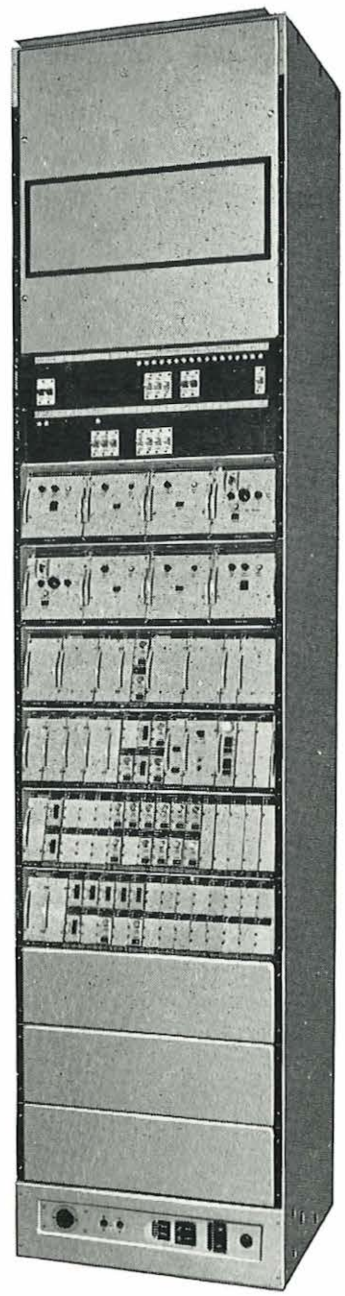
Feeder Loss:
2.2 db/100 feet
7.2 db/100 metres

Antenna	6′	8′	10′	12′
Forward Gain: (at 7500 Hz)	40.5 db	43 db	45 db	46 db
Beamwidth: (3 db points)	1.5°	1.1°	0.9°	0.8°

Power Supplies

24 volts d.c.
or 95 to 125 and 180 to 250 volts a.c.

Consumption	d.c.	a.c.
Terminal Rack	210W	285VA
Repeater Rack	365W	500VA



7500 MHz Terminal Rack includes:

Twin path Radio. Protection switching, Baseband and Supervisory Equipment all mounted on one 7′ 6″ (2.28 metres) rack

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1B/29c

5 band scrambling gives maximum security

—that's Plessey A7E Secrecy Equipment

A7E gives maximum security over both line and radio transmission links and is designed to defeat the most determined attempts at tapping. Based on the 5-band 'scrambler' device, the equipment uses a speech band of 250-3000 Hz, divided into five sub-bands of 550 Hz each. These sub-bands are modulated, filtered and re-assembled in some other sequence for transmission to the distant terminal. Interchangeable code cards at each station provide over a hundred combinations of inversions and translations. A simple switch adjacent to the telephone allows the secrecy equipment to be taken out of service at the discretion of the user and also a limited number of instant code combination changes to be made.

Transistorization has produced a compact design which is suitable for installation at subscribers' premises. The complete unit is mounted in a small rack and is operated from an a.c. mains supply.

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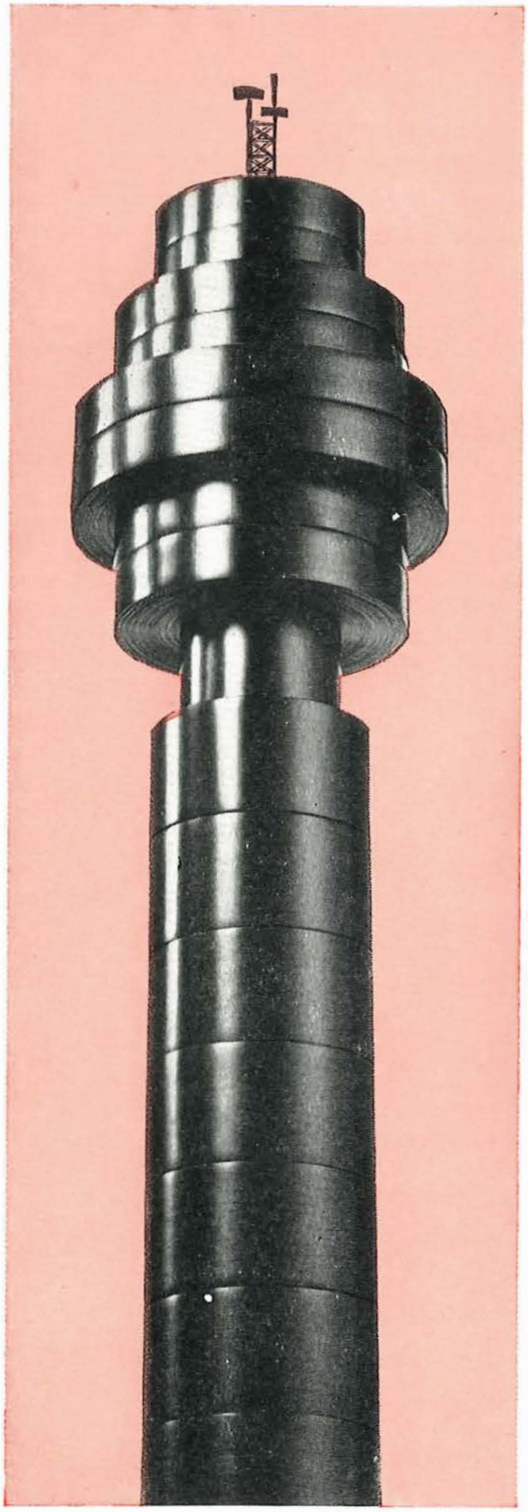

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- Compatible with polythene sheathed wires and cables.
- Available in a range of colours to B.S. 2746.

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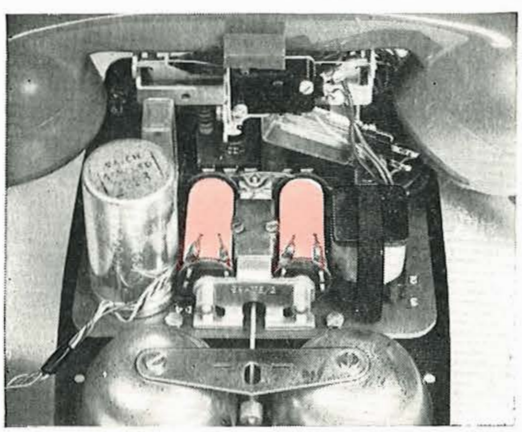
The tape is suitable for all impregnated components; since it withstands processing temperatures of 180°C and has good solvent resistance.

To find out more write for a copy of the 16-page 'Sellotape' booklet 'Electrical Taping' or discuss your requirements with one of the 'Sellotape' team of electrical tape specialists.



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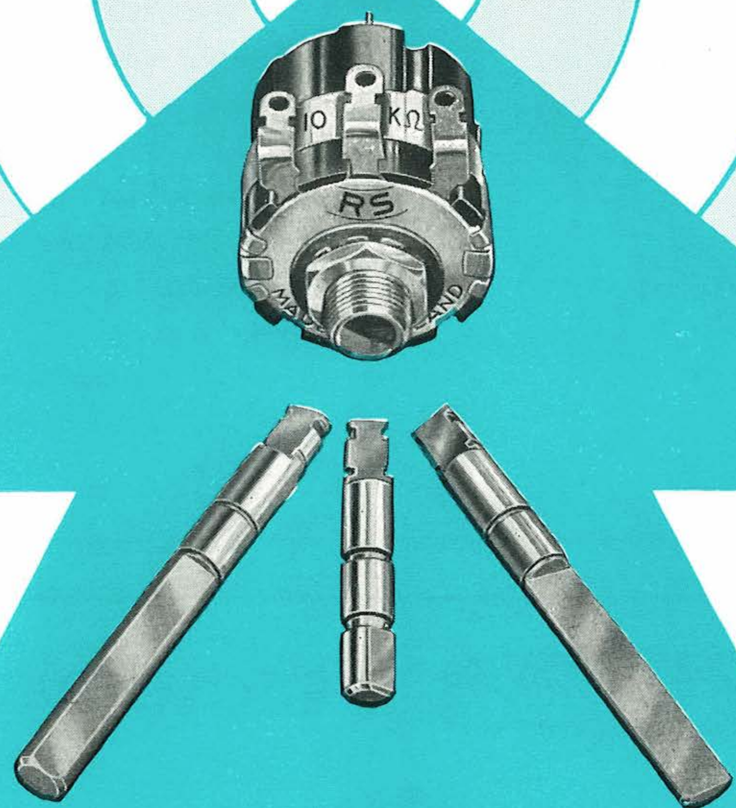

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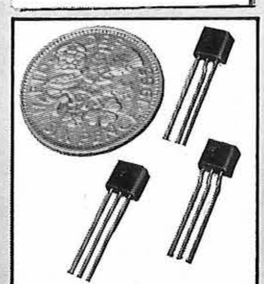
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