

The Post Office Electrical Engineers' Journal

VOL 74 PART 4 JANUARY 1982



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Contents

Editorial	307
New British Telecom Plug, Socket, Cordage and Line Jack Units P. A. Burton	308
The Ambassador Range of Telephones—Development of the Keypad and Signalling Circuitry A. N. Child and D. J. Hedges	314
INMARSAT—A New Era of Satellite Communications for Shipping P. I. Poskett	322
Wire Wrapping of Aluminium Conductors H. E. Hines	328
8·448 Mbit/s Digital Line Systems on Carrier Cables T. C. Wright and G. Archer	335
The Soil as an Engineering Material Part 2—Applications D. G. Clow	345
Information Technology Year 1982	351
The Development and Production of the Ambassador Electronic Plan System P. A. Burton and D. A. Pritchard	352
Power Supplies For Small Telecommunications Centres Part 2—AC Power Plant No. 440 A. W. Mealing	359
Teletraffic Aspects of Processor Utility Design C. Harvey	364
Replacement of Incoming Type 8 Register-Translators at Manchester Dalton J. H. Skelland	369
Changing the PMBX1A for a PMBX11A at County Hall, Truro D. K. A. Chatterton and G. D. Brown	370
Institution of Post Office Electrical Engineers	372
Notes and Comments	373
Forthcoming Conferences	374
Profiles of Senior Staff	374
System X Reprints	377
Book Reviews	368, 371, 376
British Telecom Press Notices	369, 375, 376

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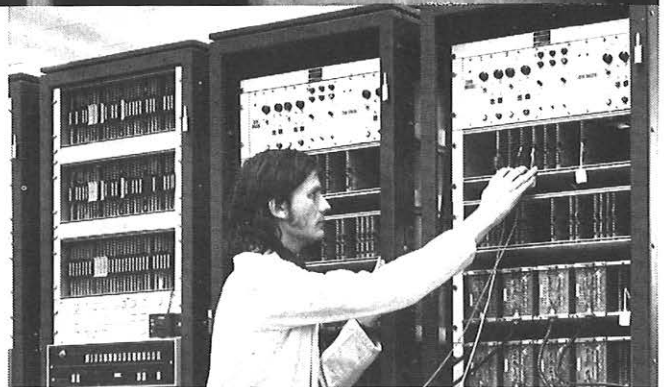


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EDITORIAL

For almost 75 years, *The Post Office Electrical Engineers' Journal* has been publishing articles on all aspects of engineering and technology as applied to posts and telecommunications. This, the two hundred and ninety-sixth issue of the *Journal* is the last under its present title. With the separation of the Postal and Telecommunication Businesses of the British Post Office, The Institution of Post Office Electrical Engineers (IPOEE) has decided to change its name, and from April 1982 it will be known as *The Institution of British Telecommunications Engineers* (IBTE). Consequent on this change, the Board of Editors of the *Journal* has decided that the *Journal* will be known as *British Telecommunications Engineering* and that the first issue under the new title will be published in April 1982. The Board of Editors wish to thank all those people who have, over the years, been associated with or who have contributed to the *Journal*. At all times in its long history, the *Journal* has endeavoured to keep the members of the IPOEE aware of the latest developments in the many areas of postal and telecommunications engineering, and, in doing so, has earned a reputation as a prestigious publication both at home and abroad.

One of the many developments currently taking place is the introduction of a new plug and socket arrangement for installations in customers' premises. An article on page 308 of this issue of the *Journal* covers the development of the new plugs, sockets and cordage which will be used for all customer installations and which will pave the way for the introduction of *phonestops* by British Telecom.

New British Telecom Plug, Socket, Cordage and Line Jack Units

P. A. BURTON†

UDC 621.395.655: 621.395.61

The new British Telecom plug, socket, cordage and range of wall jacks are described in this article, which is one of a series on the concepts and realization of the Ambassador range of telephones.

INTRODUCTION

The introduction of new telephone instruments—the Ambassador range—has given British Telecom (BT) the opportunity to

- (a) design telephone instruments that always present a standard interface condition to the line,
- (b) use parallel-connected calling devices, and
- (c) rationalize extension plan arrangements, thereby substantially reducing the number of wires used to interconnect telephone instruments.

These changes were made to enable plug-and-socket connected, installed-as-issued telephones to become the norm.

This article describes the development of the new plug and socket, the cordage used with this plug, and the new range of wall sockets—line jack units (LJUs)—used for terminating the internal cabling and accepting the plug-ended line cords. Fig. 1 shows the new plug in an LJU2.

GENERAL

The prime requirements for the plugs and sockets are that they should be

- (a) easy to use,
- (b) safe,
- (c) highly reliable,
- (d) low cost, and
- (e) capable of being made in very large quantities.

Plugs and sockets meeting these requirements can be used safely by anybody, their installation is simplified, and their reliability is either as good as, or better than, that of present items.

Because the design shape and dimensions of the cordage dictate, to a large degree, the size of the plug (and therefore the socket), a development contract was placed with a cordage manufacturer, who used a BT nominated sub-contractor for the plug and socket development. The cordage manufacturer chosen was the main contractor of the Ambassador telephone development, which simplified the liaison links between the parties concerned; this was of considerable importance because of the interactive nature of the separate developments (not always apparent at first sight), as changes to one item inevitably have an effect on the other facilities in the overall design of the instruments.

CONCEPT

The reliability of a well made screw-and-spade tag joint is high, but such connexions are often either partially made or incorrectly positioned, thereby worsening their in-service reliability. A plug-and-socket connexion that uses insulation displacement terminals automates the system, virtually eliminating human error; the reliability is then determined by the quality of the contacts.

The overall cost of any plug and socket is made up from the cost of the following items:

- (a) the main contacts (plug and socket);
- (b) any additional *make* or *break* contact(s);
- (c) the plug housing;
- (d) the socket housing;
- (e) the connexion of the plug contacts to the cordage; and
- (f) the connexion of the socket contacts to the wiring.

It had already been decided that the Ambassador telephones would use line cordage with no more than 6 conductors, thereby defining the maximum number of contacts, and that parallel-connected bells would be used to eliminate the need for the costly and fault-prone *make* contact. To keep the number of piece parts to a minimum, the aim was to produce plugs and sockets as one-piece mouldings whenever practicable. To minimize the cost of the plug-to-cordage termination, the maximum use had to be made of automation, which necessitates the use of ribbon-type cordage. This, in turn, dictated the use of plugs and sockets with in-line (side-by-side) contacts. To minimize the cost of connecting the socket contacts,

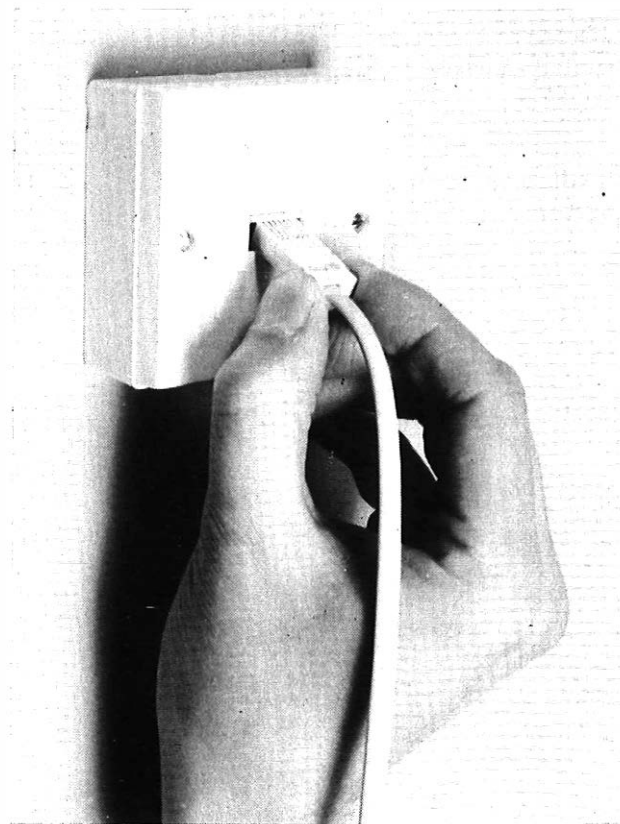


FIG. 1—The new plug and line jack unit

† Product Development Unit, British Telecom Headquarters

they were designed for automatic insertion into the moulding, prior to flow soldering onto the printed-wiring board (PWB).

REQUIREMENTS

The connectors to be developed, initially for the Ambassador range of telephones, were required to provide a cost effective, high performance plug and socket for a range of telecommunications uses; for this purpose, the following requirements had to be met.

Mechanical Requirements

The line connectors must meet the following mechanical requirements:

- (a) all sockets must be 6-way;
- (b) 4- and 6-way plugs must be the same size;
- (c) line and handset plugs must not be interchangeable;
- (d) 4 polarization codes must be available for each plug and socket (total of 8);
- (e) all sockets must reject a British Standards Institution test probe;
- (f) the plug must give audible and tactile indication of positive latching;
- (g) the plug latch must be easily used by untrained personnel;
- (h) the latch must be capable of being overridden in a snatch-out situation;
- (i) the plug and socket must be capable of 1000 engagements, with no reduction in electrical performance;
- (j) the socket must be capable of being mounted on a PWB;
- (k) the size must be consistent with the space available in modern telephones and suitable for human fingers;
- (l) the socket design must be capable of accepting a bung or of being shuttered when not in use; and
- (m) the pull-out force between plug and cord must be at least 50 N.

Environmental Requirements

The connectors must maintain their performance after being subjected to -10°C to $+55^{\circ}\text{C}$ temperature cycling, followed by 10 days in a damp heat environment.

Electrical Requirements

The connectors must meet the following electrical requirements:

- (a) electrical rating must be 200 V DC at 250 mA continuous loading;
- (b) insulation resistance must be $100\text{ M}\Omega$ minimum at 500 V DC;
- (c) contact resistance, plug to socket, including 50 mm of cordage, must be no more than $80\text{ m}\Omega$, with a maximum rise after conditioning of $20\text{ m}\Omega$;
- (d) electrical requirements must be met after
 - (i) 1000 insertions and withdrawals,
 - (ii) 50 insertions carrying rated current and voltage, followed by 10 days industrial atmosphere testing,
 - (iii) 250 hours at 55°C ,
 - (iv) 5 cycles of thermal shock from -10°C to $+55^{\circ}\text{C}$, followed by 10 days damp heat,
 - (v) fluid contamination by various specified cleaning fluids, and
 - (vi) silicone polish contamination.

CORDAGE

Because the new cordage was required quickly to align with the telephone production, the terms of reference for the

cordage manufacturer were to adopt, whenever possible, those materials being used at that time.

For the conductors, various types and formats of tinsel were considered, but none had the flexibility, strength or relatively low resistance offered by Standard British Tinsel; over many years, this has proved to be successful. A decision was therefore taken to continue with Standard British Tinsel, which consists of 4 pairs of flat copper tapes, each pair wound round a terylene thread and then all twisted round a further thread. This produces an insulated conductor with a diameter that varies between 0.85 mm and 1 mm. The overall width required for the cordage is the sum of the maximum diameters of the conductors, plus twice the sheath thickness. With a sheath thickness of 0.75 mm, 6-way and 4-way cordage are 7.5 mm and 5.5 mm wide, respectively. With ribbon-like cordage, a means of front-to-back identification is required, and this is provided by moulding a small rib in the centre of the flat face (see Fig. 2), which is positioned on the inside of a coiled cord. The insulant of the tinsel conductors is polyvinyl chloride (PVC) and may, or may not, be coloured. Manufacturers are given the option of producing single-colour conductors, using one of them for identification, or multi-coloured conductors and an identification thread.

The sheath is also made of PVC, but with the amount of plasticizer reduced to avoid the possibility of migration when the cordage is in close association with acrylonitrile/butadiene/styrene (ABS), as it is when in the cordage lead-in groove in the Ambassador telephone base.

A variety of external shapes for the cordage were tried, and it was found that if the width of the sheath was flat, when the cordage was coiled into helical sections for handset cords, it gave a rather heavy castellated effect, but by making the sheath D-shaped and keeping the curved side on the outside of the helical sections this considerably improved the appearance. This shape also aided the sheath clamp on the plug and enabled the moulding to be simplified in that area. With flat cordage there is a tendency to clamp the 2 outside conductors

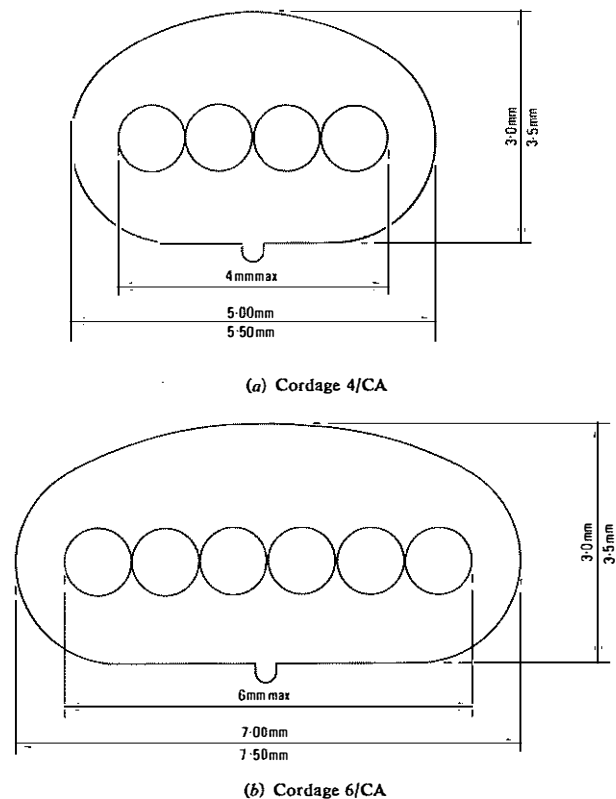


FIG. 2—Cross-section of 4-way and 6-way cordage

whilst still allowing those in the centre to move freely. This problem is considerably reduced by using a D-shaped sheath.

Some redesign of the cord grommets has been necessary to accommodate the new shape cordage and the chance has been taken to rationalize and, in some cases, cost reduce them.

The dimensional tolerances and flatness of the new cordage are held to fairly tight limits for the following reasons:

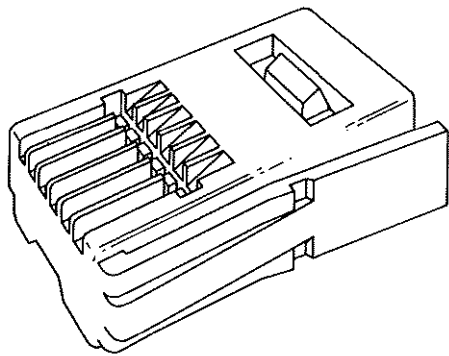
(a) It must be retained in the cord groove of the Ambassador telephone.

(b) During automatic termination, the sheath is cut and stripped prior to the insertion of the conductors into the plug, and if the conductors are not centrally placed they can be damaged by the stripping blades.

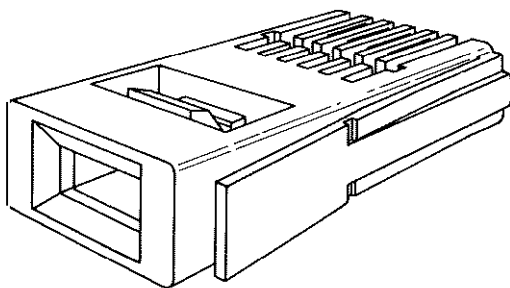
(c) Twisted cordage can be damaged during the automatic terminating process.

PLUG

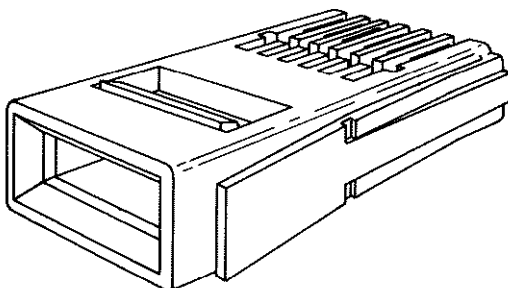
The need for automatic termination dictated that in-line contacts were required, and an elegant solution emerged to the problem of discriminating between line and handset plugs by using a side latch differently positioned (see Fig. 3).



(a) Handset plug



(b) 4-way line plug



(c) 6-way line plug

FIG. 3—Illustrations of plugs showing position of side latch

Other design options selected were as follows.

(a) Flat contacts were used for both plug and socket. This prevents the single-line wear pattern associated with circular-on-flat contacts, which results in the plating being worn away more quickly and in the contact life being shortened.

(b) Selective gold plating was chosen for the first production items because it produces the most reliable contact system, but other less-noble or non-noble metals are being considered. By putting the gold only where it is needed, the contact life is maximized for a given cost.

(c) The underside of the contacts was shaped into a blade, which is pressed down into the plug moulding to make a permanent high-pressure gas-tight joint with the tinsel conductors, using an insulation-piercing technique. (This is a technique well proven in principle and eminently suitable for high-speed automatic termination.)

(d) The plug should, if possible, be a single-piece moulding, incorporating, in addition to the side latch, both an overall cordage clamp and individual conductor clamps, all being of the knock-down type (see Fig. 5).

(e) The snatch-out feature would be obtained by ramping the retaining edge of the latch.

(f) The polarization codes should be mutually exclusive. A plug of a given code will enter only sockets having the same code.

The spacing of the contacts is primarily determined by socket constraints. As all the first generation of sockets were mounted on PWBs (and it was expected that this form would be used for the long-term solution), the socket contact tails required some form of bending operation prior to insertion in a solder pad on the PWB. The pad and track spacing needed to give the necessary voltage proofing dictated that the socket contact tails be in 2 rows of 3; this, in turn, defined a 1.5 mm socket contact spacing, which automatically means using 1.5 mm socket contact spacing for the plug contacts. This has the disadvantage that the 1 mm spaced cord conductors have to be spread to 1.5 mm when being inserted into the plug. However, because of the extra material available, each conductor can be put into a completely separate channel, thereby preventing the possibility of cross-overs and contacts between adjacent conductors. Furthermore, it eases the problem of ensuring that the contact blade strikes the tinsel centrally. These advantages easily outweigh the addition of the spreading operation.

Many variations of contact blade design were tried before the *double-dagger*, *crossways chisel point* variant emerged. Refinements of this blade resulted in the current design which, in conjunction with the separate conductor channels, consistently makes highly reliable gas-tight joints with the tinsel. Enlargements of a section of such a joint are shown in Fig. 4. Because of the shape of the contact, it can be made in strip form and automatically inserted (partially) into the slot leading to the conductor chamber, so that it is ready for the cordage termination process.

The principle upon which both the sheath and the conductor clamps depend is the same, and is illustrated in Fig. 5. The top of the moulding incorporates a *knock-down* section, which pivots using a plastic hinge; this locks in the down position to create a known deformation of (in this example) the sheath and, thereby, provides the necessary retaining force.

A 4-way plug is identical to a 6-way plug except that the outer 2 contacts are omitted, either plug being accepted by the socket, which is always 6-way.

The plugs are designed so that their termination onto the cordage can be fully automatic. Such a machine: takes a moulded plug with the contacts already partly inserted; strips a specified amount of sheath from the cordage; spreads the conductors from 1 mm to 1.5 mm; fully inserts the stripped cordage with spread conductors into the plug channels; fully presses down the contacts to form the gas-tight connexion;

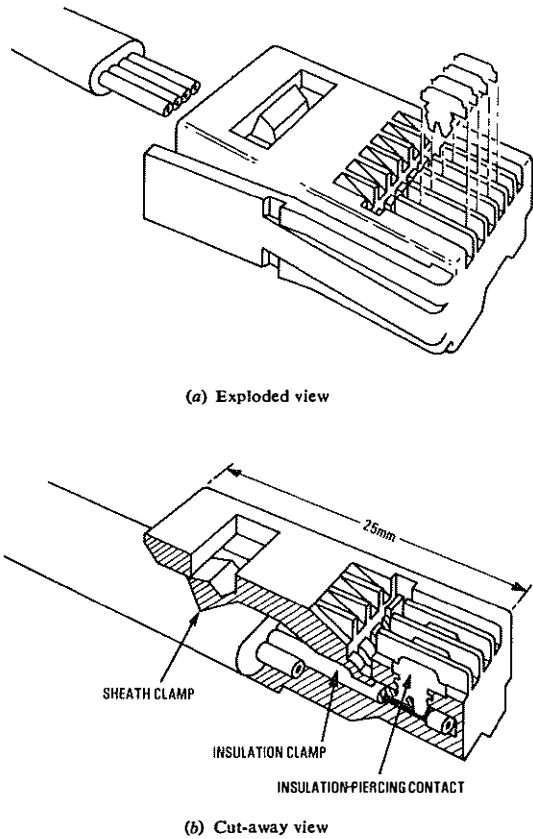


FIG. 4—Detail of cord-to-plug connexion

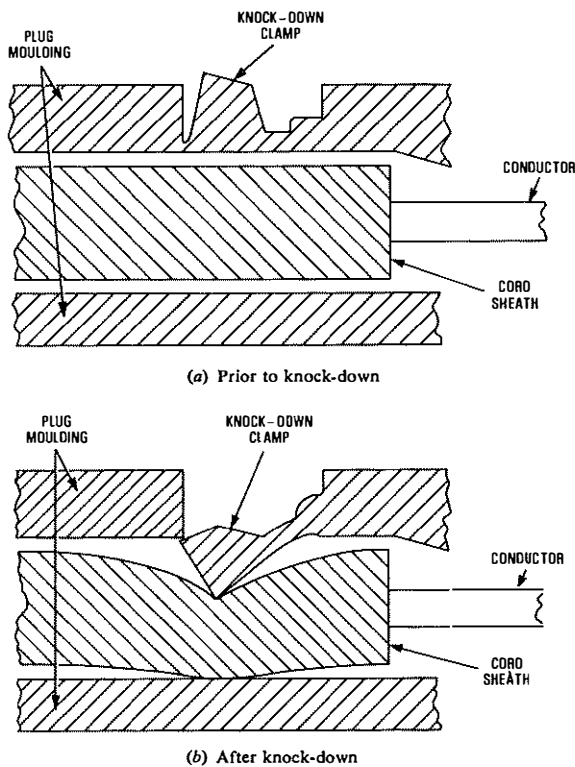
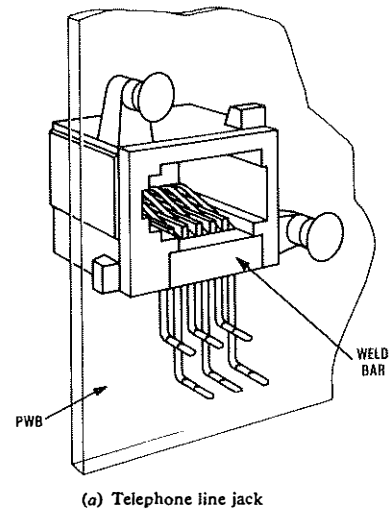


FIG. 5—Principle of sheath clamp

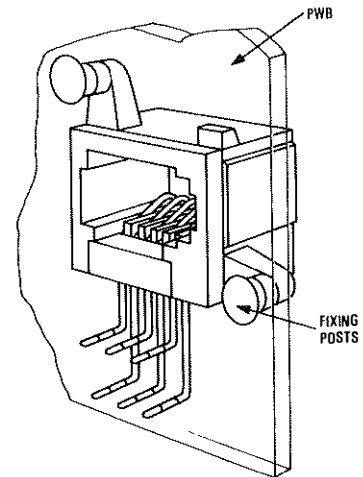
and presses down the sheath and individual conductor clamps to give the required retention force. Machines of this type can assemble plugs to cords at a very high rate.

SOCKET

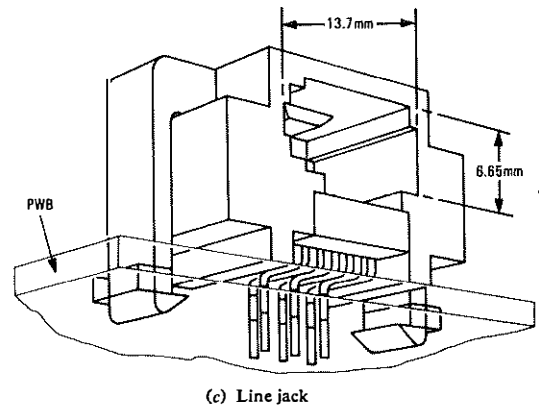
All the sockets are 6-way and use flat, relatively broad



(a) Telephone line jack



(b) Telephone handset jack



(c) Line jack

FIG. 6—Three of the varieties of socket

contacts, spaced 1.5 mm apart which are also selectively plated. The use of any intermediate joints, which could reduce the reliability of the system, is avoided by forming the contact ends into legs ready for flow soldering directly into the PWB.

While all sockets must accept all plugs having the same polarization code, they are required in various types of housing, depending on the situation in which the socket is used. There are 5 versions of the housing being manufactured at present, and more variants are expected as this connexion system becomes more widely used. Figs. 6(a)-(c) show 3 of the varieties of socket.

All the sockets are designed so that their assembly can be fully automatic. The contacts are punched in strip form, held together with a selvedge edge and selectively plated. The automatic assembly machine inserts the contacts into the moulding, performs the required bending operations, cuts off the selvedge edge, inserts a plastic bar, and then ultrasonically welds it into position to hold the contacts in place. This sort of machine can assemble sockets typically at a rate of 1000/h.

The housings used in the Ambassador telephone (see Figs. 6(a) and 6(b)) have 2 moulded legs, which are pushed through the PWB and are spin welded to fix the housing firmly to the board. The contacts protrude through the PWB so that they can be flow soldered, high temperature masking tape being used to prevent the solder reaching the main contact area.

All sockets are letter box shaped with a maximum height of 6.65 mm (see Fig. 6(c)), the contacts are set in individual grooves, thereby fully meeting the safety requirement and minimizing any chance of tiny fingers touching the contacts. The use of "sharks tooth" contacts, which could hook into anything pushed into the socket and prevent withdrawal, has also been avoided.

LINE JACK UNITS

A new range of wall jacks is being developed to permit plug and socket instruments to be used; these line jack units (LJUs) will ultimately replace a large number of terminal blocks. The range of LJUs includes the following types: surface and flush mounting units; panel mounting units; 6- and 12-outlet boxes suitable for termination of multi-core under-carpet cable; and a plug-to-double-socket adapter.

Most of the range of LJUs use the sockets previously described, in which the socket is PWB mounted and the plug entry is either through, or at the opposite end to, the PWB. On single or double outlet units, the installation wiring is terminated by using insulation-displacement terminals; the principles of this method of connexion will be described in a later issue of the *Journal*. On multiple-outlet sockets, used

in business premises, the ribbon-cable termination would be accomplished by using a Connector No. 226.

In most cases, the LJU is provided in 3 distinct types: an exchange-line master jack; a PBX master jack; and a secondary jack. The exchange-line master jack contains the socket, the bell capacitor, an opt-out-of-service resistor, a lightning protector and 2 strips of 3 insulation-displacement terminals, all these components being PWB mounted. Fig. 7 shows a LJU No. 2/1A with the cover removed to show the master jack components. Neither the lightning protector nor the opt-out-of-service resistor is fitted in the PBX master jack. The protector was removed because the protection is provided at the PBX and therefore is not required at the terminal; the resistor would serve no useful function in an extension situation. The secondary jack has no components other than the socket, insulation displacement terminals and the PWB, as only one capacitor and opt-out-of-service resistor are required per exchange line.

All the new wall-mounted LJUs contain insulation displacement terminals, and a special tool has been developed

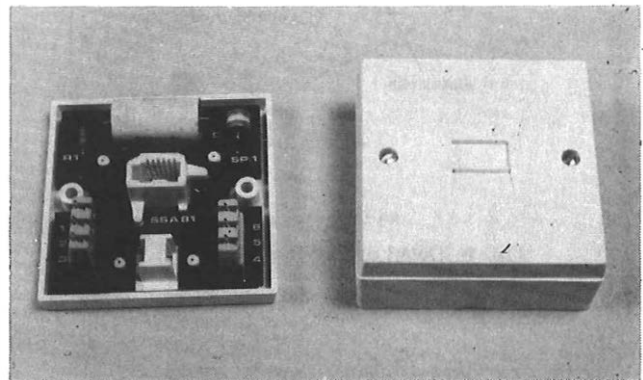


FIG. 7—LJU No. 2/1A showing the master jack components

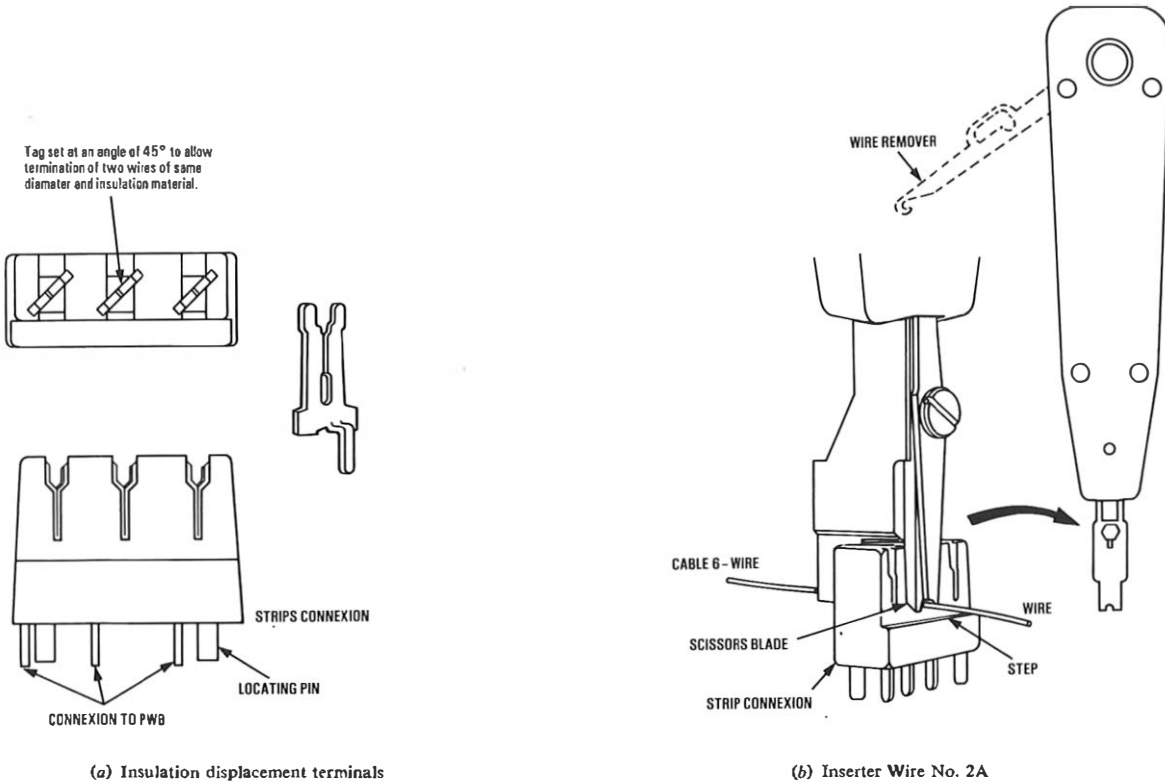


FIG. 8—Insulation displacement terminals and Inserter Wire No. 2A

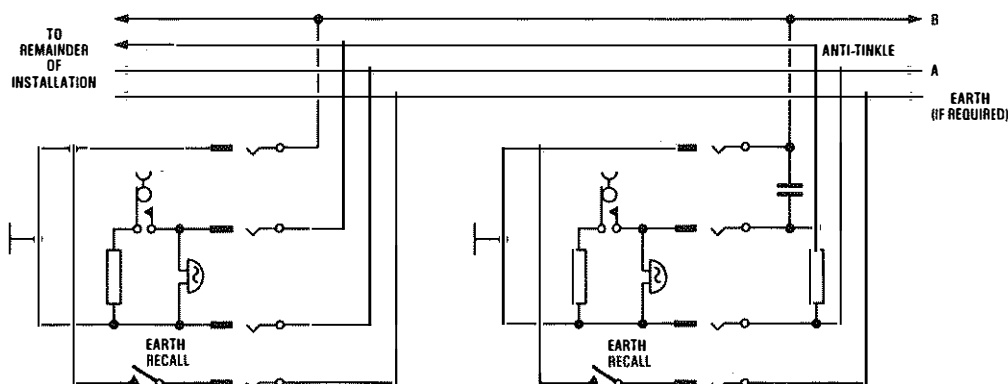


FIG. 9—Connexion of telephones using new plan wiring

for connecting the wiring to this type of tag. The tool (Insertor, Wire No. 2A) consists of a spring-loaded plunger with a shaped tip. When the unstripped wire is laid across the terminal, the tool is pressed on top of it with a pressure determined by its spring. This forces the wire into the contact slot, displacing the insulation, and making intimate contact between wire and terminal. The spring action also causes a cutter to operate, which trims off the end of the wire. Each terminal is capable of accepting two 0.5 mm wires, and these can be either terminated or through-connected wires. If the wire does not have to be cut, a block is put in the tool to prevent the spring activating the cutting blades. With this type of insertion tool, a high rate of terminations per hour can be achieved. Fig. 8 shows insulation displacement terminals and the Insertor Wire No. 2A.

The terminal numbers in the LJU PWB are reversed compared with those in the Ambassador telephone because a cord with a plug on both ends introduces an inherent reversal in the contact numbers; that is, terminal 1 on one plug connects to terminal 6 on the other. The LJU is used to correct this inherent twist.

All the single- and double-outlet LJUs have spring-loaded shutters over the entries and a moulded lead-in, so that the plug can be used to raise the shutter, thereby enabling single-handed insertion.

The smallest of the LJUs, and probably the most used, is the LJU No. 1/-, which measures 55 × 55 × 25 mm. This is virtually the smallest volume into which the necessary components can be packaged. This unit has the PWB mounted into the base, which is screwed to the wall. The PWB and socket must be securely fixed so that, when the line cord is snatched, the plug and socket part, but the socket and its PWB remain attached to the LJU base. Because the socket is so firmly attached to the base, the LJU cover can be of the clip-on type.

LJU Nos. 2/-, 3/-, 4/- and 5/- are based on the British Standards Institute type cover used for power sockets etc. In this situation, the jacks can be flush mounted or, by using a standard back box, surface mounted. The PWB is mounted close to the mounting plate and the plug enters the socket through the PWB. The LJU must be held in the hand while the wiring is being terminated. The units are screwed to the wall on the back plates with 2 fixing screws. These types of LJU can be used with standard off-the-shelf trunking. Some of these types of jack contain sockets in various combinations of master and secondary jacks.

The LJU No. 6/- and the handset jack unit are panel-mounted sockets for use on office furniture, trunking panels or switchboards. LJUs Nos. 7/- and 8/- are 6- and 12-outlet boxes used with under-carpet flat cable, which is terminated with a Connector No. 226.

NEW PLAN WIRING

As a result of the use of parallel bell connexions, the wiring for the interconnexion of telephones in basic plan systems can be simplified, and this makes these plan systems suitable for use with plugs and sockets. The more complex secretarial and/or multi-line plan systems are made suitable for plug-and socket working by adopting 4-wire electronic plan systems².

Using parallel bells and a single ringing capacitor, the extension wiring can be run with parallel connexion points provided at intervals, each being connected in an identical manner. The connexion points can be terminal blocks or LJUs, but each wire is always used for the same purpose (see Fig. 9).

CONCLUSION

This joint BT/British Industry venture has produced new plugs and sockets that meet the prime requirements of ease of use, reliability, safety and low cost, and are capable of being made in very large quantities. The plugs are connected to the customer apparatus through a new attractively shaped ribbon-like cordage, and the sockets are housed in a completely new range of LJUs developed specifically for this purpose. This type of connexion system enables the installation and maintenance of telephone instruments and associated ancillary apparatus to be considerably simplified.

ACKNOWLEDGEMENTS

The design and development of the new flat cordage was carried out by GEC Telecommunications Ltd., in conjunction with BICC-VERO Connectors who were responsible for the plug-and-socket development. The LJUs were designed by Messrs. Ebonestos, Austin Taylor and Amphenol, and the insulation displacement terminals by Messrs. Krone (UK) Ltd. as a separate development exercise. The author wishes to thank all those involved, both in Industry and BT, for all their endeavours.

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The Ambassador Range of Telephones— Development of the Keypad and Signalling Circuitry

A. N. CHILD, B.SC., C.ENG., M.I.E.E., and D. J. HEDGES, B.SC.†

UDC 621.395.61: 621.395.631.3

This article describes the development of a new design of keypad and associated signalling circuitry for the Ambassador range of telephone instruments. It goes on to describe the repertory-signalling variants for this range of instruments.

INTRODUCTION

The design and development of the Ambassador range of telephone instruments, and the production of the *basic* instrument have been described¹ in an earlier issue of the *Journal*. This article describes the developments in the keypad and signalling circuitry that have taken place since 1975, when an article² in the *Journal* described the operation of these features for a 700-type press-button telephone. The keypads and signalling circuitry now described are capable of being fitted into many different types of telephone chassis; for example, the Ambassador's signalling circuit has already been incorporated in the 700-type and the 722-type (Trimphone) instruments.

The Ambassador range of press-button basic telephones are equipped either with self-contained (SC) or multi-frequency (MF4) signalling circuitry. No DC Code-C capability has been provided as this method of signalling is being phased out. In addition, enhanced variants in the range have the ability to store 10 telephone numbers and the last number manually keyed. These so-called *repertory* types are also equipped with either SC or MF4 signalling. All versions employ a common design of keypad, although each has a unique combination of button legends.

THE KEYPAD

In specifying the design parameters for the Ambassador's keypad, due consideration was given to the experience gained with previous designs. A collapse-action was retained; this ensures that adequate button travel is achieved by lowering the necessary operating force significantly once the initial force has been overcome. However, the operating forces required of the user, and the resulting button travel, were both reduced to be more in line with many modern calculators, as illustrated in Fig. 1. The button size and layout were also amended, as shown in Fig. 2. Smaller sized buttons allow greater row and column spacing between adjacent buttons, which is aesthetically pleasing, and minimizes the number of double-button depressions.

Reliability of operation was a problem with older designs of keypad and in many cases the least reliable parts were the common contacts and their associated actuating mechanisms. The common contacts closed each time any of the keypad's buttons was depressed, their function being to switch the telephone from a TRANSMISSION state to a SIGNALLING state. They were often actuated by various forms of sliding plates that were made to move sideways by the button stroke. The common contacts added cost, size and complexity to the keypad, lowered reliability, and adversely affected the button's feel to the user. To overcome these problems, it was decided, at an early stage, that no common contacts would be provided on the Ambassador range, and that the common-switching function would be performed by electronic components.

With no requirement for common contacts, the keypad

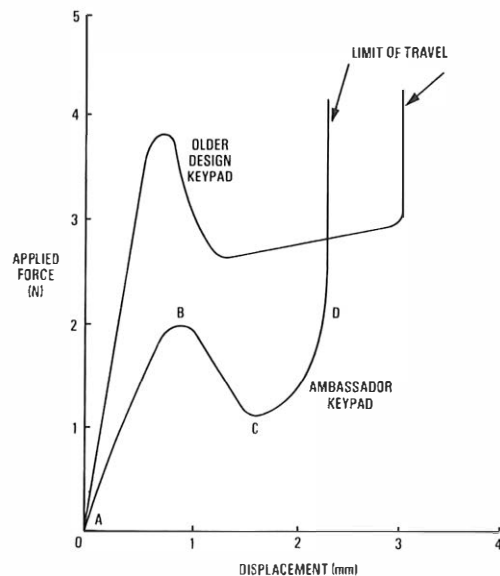
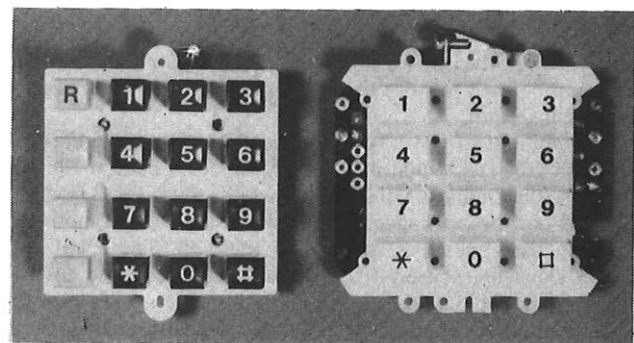


FIG. 1—Comparison of applied-force/button-displacement characteristics of the Ambassador keypad and an older-design keypad



(a) Ambassador keypad

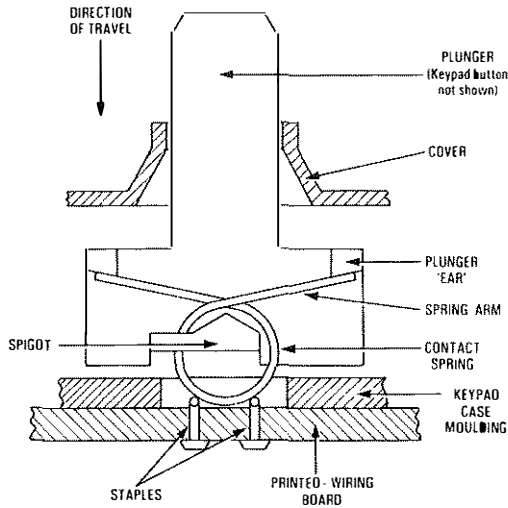
(b) Older-design keypad

FIG. 2—Comparison of 16-button Ambassador Keypad and 12-button older-design keypad

designers could concentrate on the contact associated with each button. A good metallic contact is achieved not only by correct choice of materials, but also by a good design which allows contact to be made with adequate contact pressure while providing a degree of wipe between the mating parts to remove any surface impurities.

The Ambassador's keypad employs a novel technique to achieve these aims, and this is illustrated in Fig. 3. For each button, 2 noble-metal-plated wire staples are positioned parallel to each other and about 2.5 mm apart on a printed-wiring board. They are normally electrically isolated from each other, but are electrically connected when a noble-metal-plated wire spring is made to rest on them. The spring has 6 turns and, therefore, reliability is enhanced because 6 contacts

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Note: The press-button plunger is approaching the end-stop on the keypad case moulding, and the spring has just made contact with the staples.

FIG. 3—Ambassador press-button-contact system

are made between the spring and each staple. The spring imparts contact pressure onto the staples from 2 arms which bear onto ears on the plunger when the user operates the button. This process also winds up the spring, giving a wiping action to the contact areas.

The spring/staples system is designed to make contact late in the button's travel to ensure that the keypad is not operated if the user accidentally touches it. The operate characteristic shown in Fig. 1 is primarily achieved by the movement of an actuation spring which, like the contact spring, is located on a spigot protruding from the plunger. The actuation spring also has arms, and these move on ramps which are integral features of the keypad's case moulding (see Fig. 4).

Initial operation of the button causes the spring's arms to slide down the ramps, winding the spring's coils, and increasing the force required to operate the button. This steady increase in operate force is shown between points A and B in Fig. 1.

Further operation of the button causes the spring's arms to slide to a point where the ramp angle changes abruptly. At this point a collapsing action is achieved, which ensures full stroke travel; that is, from point B to C of Fig. 1. Further pressure from the user causes the plunger to bear against

faces of the keypad case moulding, thereby resulting in minimal further travel despite rapidly increasing operate forces, as characterized by points C to D of Fig. 1.

When the user reduces pressure on the button, the spring can unwind, and its arms slide back up the ramps returning the button to its up position.

SIGNALLING CIRCUITRY

The purpose of the signalling circuitry is to receive information from the user, via the keypad, and to send appropriate signals to the telephone exchange via the subscriber's line.

SC Signalling

SC signals are loop-disconnect pulses which are sent to line at a nominal speed of 10 pulses/s with a break-to-make ratio of 2:1. Their sending speed to line is much slower than the keying rate of the user and, therefore, the telephone has to be provided with a store to remember the digits keyed.

MF4 Signalling

MF4 signals are speech-band tones which are sent to line in pairs at the speed they are entered into the keypad by the user. Each digit is represented by a unique combination of 2 frequencies; each being selected from a different group of 4 frequencies. These 2 groups occupy different portions of the speech band and are known as the *low group* and the *high group*. The signalling system thus has a capacity for 16 signals and is known as a *one-out-of-four-plus-one-out-of-four* system. The Ambassador MF4 telephones, in common with all previous British Telecom (BT) MF4 telephones, utilize only 12 of the signals (designated 0-9, * and □) and consequently only 3 of the high-group frequencies are used. The four remaining signals, designated A, B, C and D, were allocated when the signalling system was first devised for use during end-to-end data transmission across the network and for exchange-based supplementary-facility control; they were incorporated into the CCITT† recommendation for MF4. In practice, they are seldom, if ever, used for data transmission, and will not be used for supplementary-facility control on System X exchanges.

† CCITT—International Telegraph and Telephone Consultative Committee

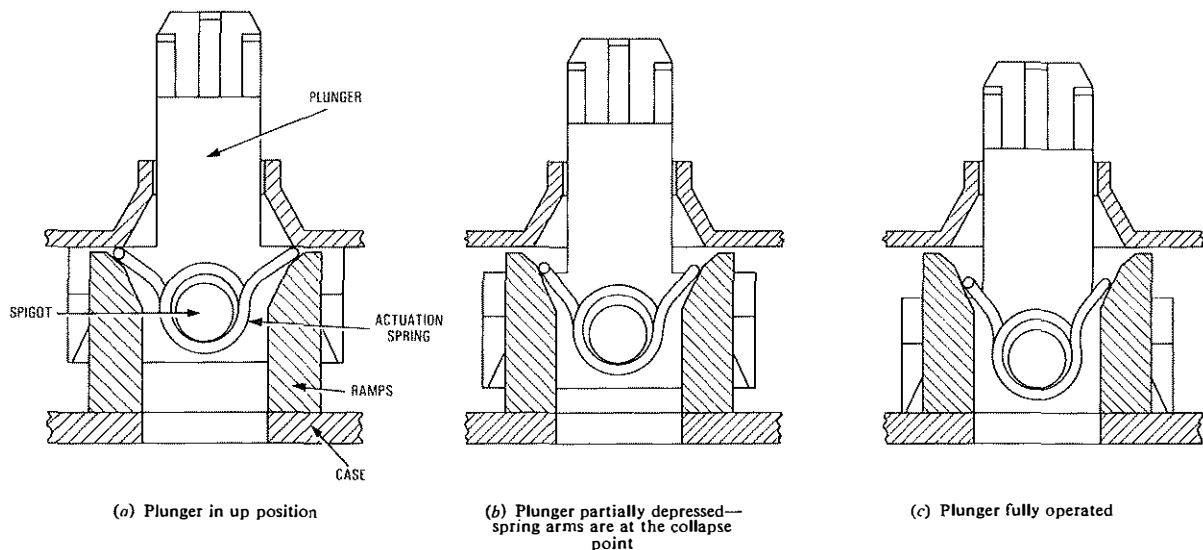


FIG. 4—Method of achieving collapse action

Exchange Recall

Most Ambassador press-button telephones are equipped with an *exchange recall* signal controlled from a button marked R on the keypad. When operated during a call, the R button enables the user to begin setting up supplementary facilities such as *hold-for-enquiry* and *wait-on-busy*. The facilities available depend on the exchange to which the telephone is connected, and the type of exchange also determines which of 2 types of recall signal is required; either *earth recall* or *timed-break recall*.

Earth recall has been in use for many years on PABX systems. Operation of the R button connects an earth directly to one leg of the line. *Timed-break recall* on the other hand is a newer system for use with public telephone exchanges equipped with supplementary facilities, such as System X. Operation of the R button breaks the loop for a timed duration range of 53–103 ms. On the MF4 telephone, this is achieved by a discrete electronic circuit. On the SC telephone, a digit-1 break is used because this is of duration 67 ± 3 ms and this lies within the acceptance range of the exchange-based detector. Therefore, in an SC telephone, the R button can be connected in parallel with the digit-1 button and no additional circuitry is needed.

Timed-break recall is used on public exchanges because of the difficulty in providing an earth to all telephones on this type of installation. Only exchanges of recent design, such as System X, will be able to detect this signal; these exchanges will usually be able also to receive MF4 signalling, and it is anticipated that *timed-break recall* will usually be provided only on the MF4 type of press-button telephone.

SC SIGNALLING CIRCUITRY

Two versions of SC signalling circuitry were developed for the Ambassador range. The main contractor for the Ambassador project (GEC Ltd.) developed one based on a complementary symmetry metal-oxide semiconductor (CMOS) integrated circuit (IC). A sub-contractor (TMC Ltd.) developed an N-channel metal-oxide semiconductor (NMOS) IC. The GEC circuit will be described and is shown in Fig. 5. The TMC circuit is broadly similar in operation.

The 2 versions of the SC signalling circuitry were developed to compare the suitability of the IC production processes in this application. NMOS is the proven lower-cost process and

is simpler to fabricate, but consumes more power; CMOS, on the other hand, requires a less complex peripheral circuit.

Circuit Operation

The heart of the signalling circuit is the IC, a 16-pin dual-in-line (DIL) device employing CMOS technology, which is characterized by low current consumption—an important factor in SC circuitry. The IC receives information from the keypad and is powered solely from the line (that is, no batteries or external power supplies are required). It outputs control currents to switching transistors, which perform *impulsing* and *muting* (off-normal) functions.

When the telephone is IDLE, hook switches S1A and S1B are OPEN and the signalling circuitry is powered down. To set up a call, the user lifts the handset, closing S1A and S1B. Line current flows to the signalling board via the surge limiting inductor L1, and power is applied to the IC via transistor TR5 operating as a constant-current generator of 450 μ A. As the IC's supply voltage ($V_{DD}-V_{SS}$) rises, the buffer store, which will hold the digits keyed, is automatically reset. When the supply voltage reaches the operating level, the IC's *off-normal* output (O/N) is held HIGH and the *impulsing* output (IMP) is held LOW.

This causes the switching transistors TR1 and TR2 to turn ON, allowing line current to flow through the telephone transmission circuit to permit transmission. This current flow is detected by the exchange as a LOOP condition and *dial tone* is returned. This entire sequence, from the closing of the hook switches to the establishment of transmission takes less than 100 ms.

When a keypad button is operated, the IC immediately starts the clock—a small ceramic resonator operating at 559.7 kHz ($\pm 2\%$), which controls the timing functions (pulsing speed and ratio, inter-digit pause (IDP), etc). The clock starts within 1.5 ms, and the IC, also during this time, turns its O/N output to OFF (low) and its IMP output to ON (high). This switches the flow of loop current from transistors TR1, TR2 and the transmission circuit to transistors TR3, TR4 and Zenor diode D5 (4.3 V).

The IC times out a 800 ms pre-digit pause before pulsing commences. Pulsing comprises a series of BREAKS of 66 ms duration interspersed with MAKES of 33 ms duration giving a speed of 10 pulses/s and a ratio of 2:1. The BREAKS are

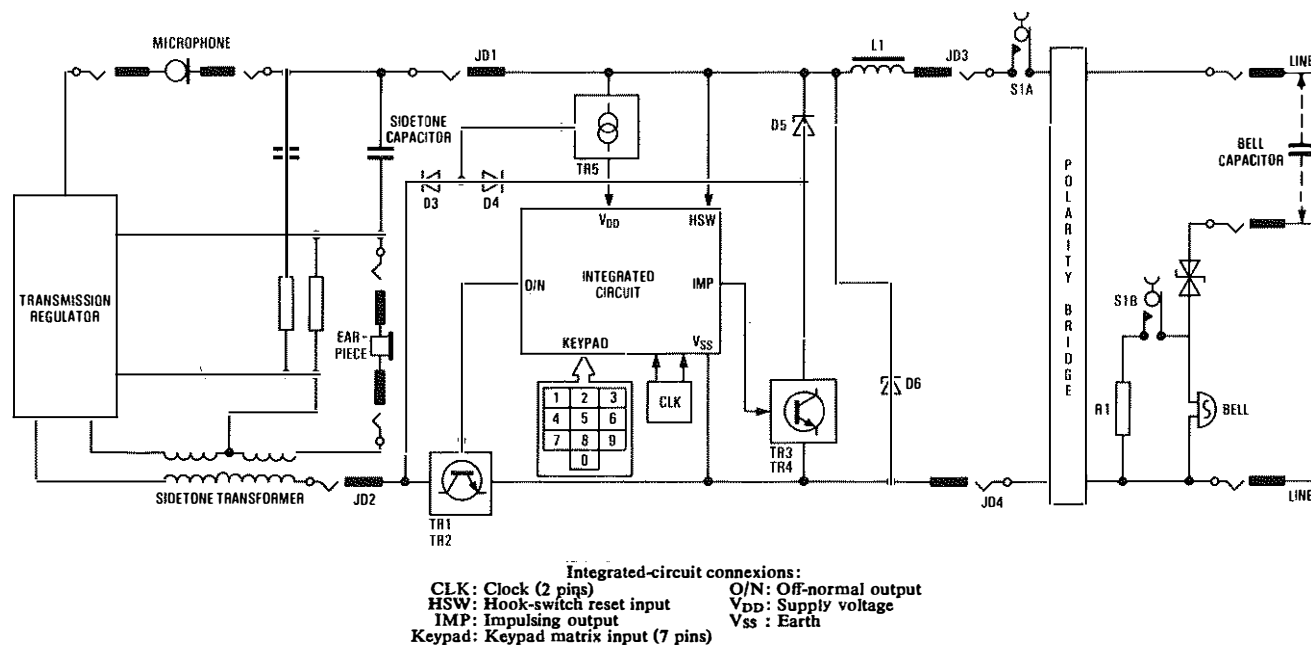


FIG. 5—Self-contained basic-instrument circuit (GEC Ltd.)

achieved by turning OFF transistors TR3 and TR4; the MAKES occur when transistors TR3 and TR4 are turned ON again. During the BREAKS, diodes D3 and D4 turn off the constant-current generator (TR5) to ensure that the total current flowing through the telephone is less than $100\ \mu\text{A}$. The IC supply voltage is maintained during this period by current from a reservoir capacitor. Zenor diode D6 ($150\ \text{V}$) and the spark quench circuit (bell capacitor and resistor R1) limit the voltage transients that occur when the loop is broken.

Second and subsequent digits are pulsed out in the same way, the IC timing an IDP of 850 ms before each digit. Keypad buttons can be operated at any time during the pulsing out, the IC storing the digits in the buffer store in the correct order and pulsing them out at the correct speed. BT requires press-button telephones to be able to store and pulse out telephone numbers of up to 21 digits.

After the last MAKE of the last digit keyed has been sent, the IC restores the telephone to normal speech transmission by turning ON TR1 and TR2, and simultaneously turning off TR3 and TR4. The clock is also turned OFF and the IC is powered down to a QUIESCENT state awaiting any further keypad input. If the user clears the call at any time by operating the hook switches, then this is detected by the hook-switch reset input (HSW). The IC times this input and resets itself only if the hook-switch "flash" is longer than 300 ms. Breaks of shorter duration are treated as probably being caused by spurious breaks or noise on the line and are ignored.

Evolution of the SC Circuitry

A comparison between the circuitry just described and the state-of-the-art in 1975² shows considerable differences in physical design and realization, yet very similar overall circuit performance.

The design philosophy in the 1975 circuitry was to retain the normal dial-telephone circuit and to replace the dial's OFF-NORMAL and IMPULSING contacts with reed-relay contacts and mercury-wetted contacts respectively. The relays were controlled by circuitry built around an IC associated with an inductive oscillator circuit. The current consumption of the whole circuit was sufficiently high to prevent it from being line powered during the call, and a nickel-cadmium recharge-

able battery with an attendant charge-switching-unit had to be provided, adding to the cost of the telephone.

With the aims of reducing cost and improving reliability while retaining performance quality, development programmes succeeded firstly in dispensing with the secondary battery. This design retained the dial-telephone circuit configuration but replaced the dial with an off-normal relay, and used transistor impulsing. Its power consumption was much reduced, mainly as a result of improvements in IC technology and reduction in peripheral circuit complexity.

This enabled power to be derived from the line during the IDP and MAKE pulses, and stored in a reservoir capacitor large enough to maintain the supply voltage to the IC during the BREAK pulses.

A further cost reduction was achieved by the subsequent development of a design without relays or batteries, using switching transistors for both *off-normal* and *impulsing* functions. This necessitated converting the transmission circuit into a 2-wire circuit by removing the central gravity switch, reproducing the side tone-capacitor function of the bell capacitor by using an additional capacitor, and placing the signalling circuitry between the transmission circuitry and the line. This enabled the *off-normal* function to be achieved by a transistor which could be turned OFF and thus disconnect the entire transmission circuit, compared with a dial which shorts out both handset transducers to achieve this function.

Subsequent developments leading up to the Ambassador's circuitry have sought to simplify further the design, concentrating on cost reduction and improved reliability. For example, these developments resulted in the use of a single-contact keypad and the replacement of the bulky and expensive LC-type oscillator clock by a smaller, lower cost, but much more accurate ceramic resonator. IC technology and the scale of integration have also improved, allowing much more of the peripheral circuitry to be integrated.

The use of a transistor as a pulsing contact gives an inherently different pulsing characteristic compared with a traditional dial. The accuracy of speed and ratio from the Ambassador SC telephones is considerably better than that of a dial telephone. This is due mainly to the stability of the ceramic-resonator clock, and results in a typical worst-case accuracy, when new, of $\pm 1.5\%$ for both speed and ratio,

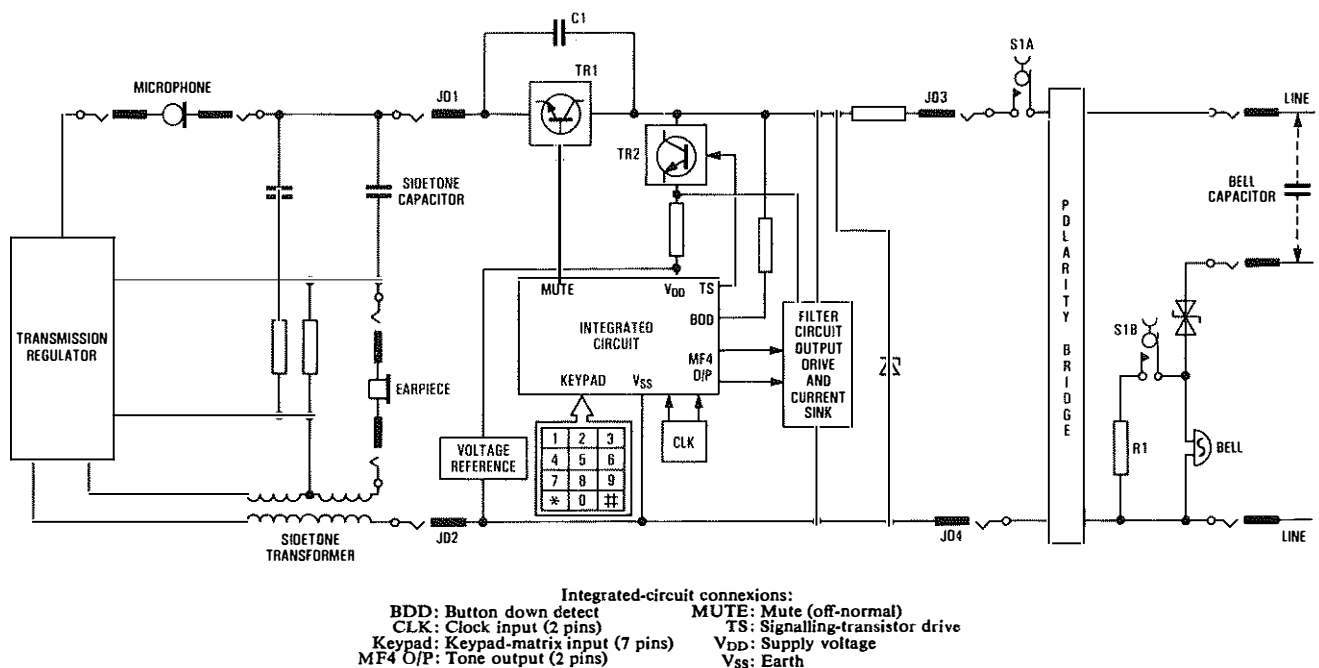


FIG. 6—MF4 basic-instrument circuit (TMC Ltd.)

whereas $\pm 10\%$ and $\pm 5\%$ respectively are the corresponding dial figures (the effect of ageing is also much less than for a dial). Offset against this, to a certain extent, is the increased pulse distortion due to the higher voltage drop across the telephone during the MAKE pulses, and also to the Zener voltage clamp provided to limit transients during impulsing. The transients are caused by the inductive nature of exchange feed bridges; considerable overshoot is usually experienced on both the leading and trailing edges of each BREAK pulse, and peak voltages of up to 250 V are not unusual. The clamp (diode D6 in Fig. 5) was introduced to allow the use of switching transistors of a lower voltage rating, which cost less and are more readily available. A clamp of 150 V is used because tests showed this to be the lowest usable clamp voltage—lower voltage ratings cause a rapid and accelerating increase in pulse distortion. On balance, the pulsing performance of the Ambassador SC telephones is better than that of a comparable dial telephone, and this is especially true when the production spread of performance parameters is considered.

MF4 SIGNALLING CIRCUITRY

The MF4 signalling IC used in Ambassador telephones uses static NMOS logic with static transistor loads. It was developed by TMC Ltd., along with its peripheral circuitry (see Fig. 6).

Circuit Operation

The IC is a 16-pin DIL device. It receives digit information from the keypad and power from the line. It generates internally the 2 MF4 tones corresponding to the digit selected, and outputs these to line.

When the telephone is MUTE, hook switches S1A and S1B are open and the circuit is powered down. When the user lifts the handset, S1A and S1B close and power is applied. The IC is partially powered via pin BDD and, in the absence of a keypad button depression, it drives transistor TR1 from the MUTE pin. Transistor TR1 turning ON switches the telephone into the transmission mode. In order to minimize speech degradation, TR1 has to be driven into saturation, and to achieve this a small current (typically 0.5 mA) is diverted through the IC.

When any keypad button is depressed, a button-down detect circuit in the IC recognises the event and turns TR1 to the OFF state and TR2 to the ON state in a controlled manner so as to minimize switching transients. TR1 turning OFF and TR2 turning ON enables all the line current to be offered to the IC; however, all but about 2 mA of line current is unwanted and is shunted away via the current sink. The telephone is now in the signalling mode and the available power is used to start the clock. This consists of the same ceramic resonator as used on the SC telephone, and a master frequency of 559.7 kHz is generated in conjunction with the oscillator circuitry in the IC. This master frequency is used by the IC to derive the MF4 tones.

Of the many techniques of digital sine wave synthesis, one of the simplest is a stepped approximation consisting of 8 samples each of one of 4 voltage levels (see Fig. 7). More exact approximations require less filtering to achieve a given harmonic purity, but result in more complex generation logic. A step function approximation to a sine wave generates unwanted harmonics and a 4-step approximation requires a 2-stage RC filter circuit to achieve an acceptable harmonic purity.

The waveform of Fig. 7 contains harmonics at $((8n) \pm 1) \times$ the fundamental frequency) where $n = 1, 2, 3$ etc. The amplitudes of these harmonics obey the $1/f$ law; that is, decrease at 6 dB/octave. The lowest frequency harmonic generated is the seventh, which has an amplitude of -17 dB with respect to the fundamental.

Fig. 8 shows a resistor-transistor network which can

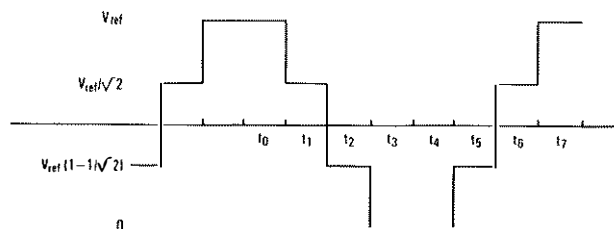


FIG. 7—4-level stepped approximation of sine wave

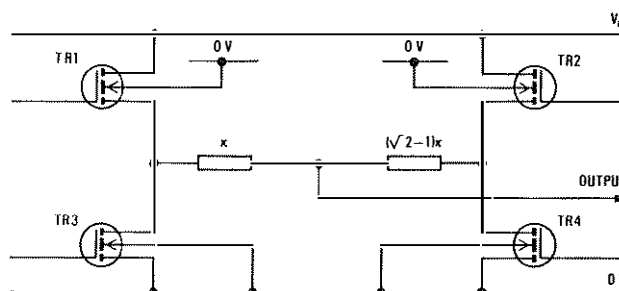


FIG. 8—Stepped-waveform generator

generate the stepped waveform of Fig. 7. Two such networks are required, one for the low group frequencies and one for the high group frequencies. With transistors TR1 and TR2 ON at time t_0 , the output is at V_{ref} . At time t_1 , TR2 and TR3 are ON giving an output of $V_{ref}/\sqrt{2}$. At time t_2 , TR1 and TR4 are ON giving an output of $V_{ref}(1 - 1/\sqrt{2})$ and at time t_3 , TR3 and TR4 are ON giving an output of 0. The 4 stages are repeated in reverse order in times t_4 to t_7 to complete the cycle.

In order to control accurately the tone output levels, the voltage rail V_{ref} has to be well defined and therefore its voltage is determined by a reference circuit external to the IC. The 3 logic waveforms needed to drive the network of Fig. 8 are derived from a simple $\div 8$ counter/decoder, which is clocked at 8 times the tone frequency required. The clocking frequency is itself derived by dividing the fundamental frequency; each tone requires a unique division factor.

As an example, to generate 1209 Hz, which is one of the 7 MF4 tones, the fundamental frequency of 559.7 kHz is divided by 58 to give 9650 Hz. This frequency is used to drive the $\div 8$ counter, resulting in a tone frequency of 1206.25 Hz, which is an approximation to 1209 Hz with an error of 0.227%.

Using the above technique, the IC generates the 2 MF4 tones corresponding to the button depressed, and these are sent to line. They are also returned to the user's ear via capacitor C1 to give him confidence that the system is responding to his keying.

When the user removes his finger from the keypad, older designs of MF4 telephone would immediately cease emitting tones and revert back to the speech transmission mode. However, the Ambassador MF4 IC has 2 features called *signal stretching* and *speech holdover*, which have been incorporated in the IC to improve the overall success rate of MF4 signalling (the development of these features is discussed below).

Replacement of the handset opens S1A and S1B, removing all power from the telephone.

Evolution of the MF4 Circuitry

Although performing the same basic functions as its pre-

processors, the Ambassador's MF4 circuitry just described demonstrates that considerable advances have been made in the past 7 years.

In 1975, virtually all the world's production of MF4 telephones used complex keypads that often consisted of 2 MAKE contacts for each button, and common contacts that operated each time any button was depressed and which altered the telephone from transmission to signalling modes. The tone generator was usually an LC oscillator using a single transistor which was made to oscillate by employing transformer feedback between its emitter and base circuits. Each frequency was selected by tapping the transformer's windings using a contact associated with the button depressed. A capacitor was applied across the tapped windings by the same contact to resonate with the transformer. Two such capacitor/transformer pairs were required, one for each of the 2 tone groups, and therefore each button required 2 contacts.

A number of MF4 ICs began to be available in the mid-1970s. However, most of these merely replaced the LC oscillator with digital synthesis; many, for example, still required the complex keypads to select the tones and switch the telephone mode. After examination of those available, BT decided to have developed a new IC fully optimized to the Ambassador's design philosophy and, in particular, exploiting the inherent capabilities of ICs when compared to their discrete predecessors.

To minimize the cost and size of the keypad and to improve its reliability, it was decided to employ a single-contact-per-button type with no common contacts. In place of common contacts, transistor switches were employed (TR1 and TR2 of Fig. 6). In addition, the timing and memory capabilities of integrated circuitry were exploited in 2 ways: signal stretching and speech holdover. These features have been designed to improve the success rate of the MF4 signalling system as a whole, in correctly interpreting the digits selected by the user.

Signal Stretching

Older designs of MF4 telephone emitted tones totally under the control of the user; that is, the duration of the tones sent to line was determined by the time the user's finger operated the keypad button. MF4 tone receivers in the telephone exchange require that the tones shall be present for at least typically 20-40 ms before they are recognized as valid MF4 tones. Unfortunately, it is possible to operate some keypad buttons within such short durations, albeit on a small percentage of occasions. Thus, there is a small possibility that the MF4 receiver will miss some digits, and the situation is made worse by the trend to lighter-action low-travel button operations. To solve this problem, the Ambassador MF4 IC was specified to stretch any short duration tones to a minimum of 70 ms; that is, on short button-down durations, the tones are made to continue after the button is released (see Fig. 9).

MF4 receivers also require a minimum period of no tones between digits (that is, during the IDP) in order to discriminate between a single digit temporarily disrupted by noise, and 2 valid digits. Signal stretching eats into the IDP period and, therefore, there is a danger that the receiver would invalidate 2 valid digits. To prevent this, a guaranteed minimum of 70 ms IDP was also specified for the Ambassador IC.

Thus, any digit uses a minimum of 70 ms for tones and 70 ms for IDP; that is, a total of 140 ms. However it is possible that a user could press and release one button and press a second button within 140 ms; therefore, to allow for this, the beginning of tone output for the second digit has to be delayed until 140 ms has elapsed from the start of the first digit. To achieve this, a digit buffer store is provided on the IC, in a similar manner to that provided on the SC IC. However, since SC signalling is much slower than MF4, there

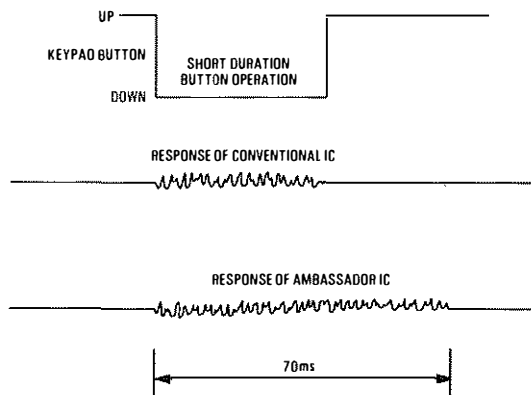


FIG. 9--Signal stretching to 70 ms

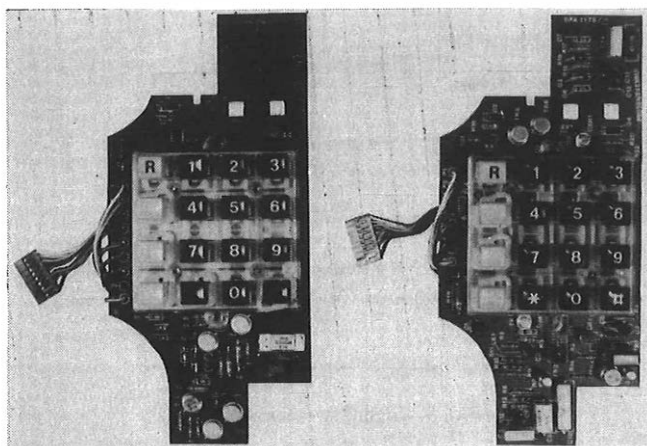
is clearly much less storage needed on an MF4 IC. An exercise was undertaken in which operators experienced in the use of keypads were encouraged to key very simple numbers as fast as they could on a very low-travel light-action keypad. The results of this exercise demonstrated that, while a keying rate as high as 8 digits/s can be attained on keying one digit, it cannot be sustained, and the rate for fast keyers drops to just over 6 digits/s when keying 3 or more different digits. From this, to ensure that the circuit can respond to guarantee that no digits are lost, the IC must accept 3 digits keyed within 225 ms from the start of the first to the end of the third, but that it need not handle 2 digits pressed and released within 70 ms. Analysis of this requirement demonstrated that only the single digit store, already provided to hold the digit being sent, was required provided this was controlled by a flag that prevented overwrite by the present digit until the previous digit had been correctly sent.

Speech Holdover

The frequencies of MF4 tones are in the audio band and, therefore, MF4 receivers are susceptible to being confused by speech that imitates the tones. The receivers use various methods to minimize this problem, but there is still a small risk of the receivers interpreting parts of speech as MF4 tones. Older keypad circuit designs revert to speech transmission mode on each button release and therefore speech may be present between digits, possibly resulting in misrouted calls. To alleviate this problem, the Ambassador MF4 IC employs a technique called *speech holdover*. After sending a digit's tones to line, the IC starts a timing circuit. This circuit prevents reversion to the speech transmission mode during the IDP until the time period has elapsed; that is, transistor TR1 of Fig. 6 is held OFF and TR2 held ON during the time period, although no tones are being sent. The choice of the optimum duration for the time period was a compromise. A long period, say 5 s, would virtually guarantee that reversion to the speech mode would not occur during the IDP, even for the slowest keyers. However, the last digit keyed also initiates the speech holdover circuitry. Thus the reception of speech or system tones that are sent immediately after the last digit sent is impaired. To minimize this effect, a compromise time of 1 s was chosen for the speech-holdover time period.

Speech holdover has a second advantage in designs of telephone that send an undesirable voltage transient to line (and to the user's ear) during switching between transmission and signalling modes; keeping the telephone in the signalling mode for most keying habits, by employing speech holdover, can drastically reduce the number of transients sent.

An advantage that unfortunately will never be realized is that if all MF4 telephones had signal timing and speech holdover, then MF4 receivers could be drastically simplified and, therefore, reduced in size and cost.



(a) Self-contained

(b) MF4

FIG. 10—Self-contained and MF4 signalling boards

CONSTRUCTION

Fig. 10 shows the SC and MF4 signalling boards for the basic versions of telephone. The actual signalling circuitry is situated on each board below the keypad and it is notable that separate evolution of the 2 signalling systems has resulted in a very similar number of components. The SC board shown is the one developed by the main contractor. Earth recall is provided using the R button. The MF4 board shown is the one developed by the sub-contractor. Timed-break recall is provided by the components situated above the keypad and this facility is invoked by the R button.

REPERTORY SIGNALLING

In addition to the SC and MF4 basic telephones described above, repertory-signalling variants are available in the range. These telephones offer the user 10-number storage and automatic repeat-last-number facilities which allow regularly used numbers, and numbers set up manually but failing due to ENGAGED, NO REPLY etc., to be called by operating only 2 buttons. The repertory-signalling instrument circuitry is very similar to the basic instrument circuitry except that, in addition, a total of 11 telephone-number stores are provided on the IC. These stores are similar to those often found in pocket calculators, and they can be written into and overwritten, but they cannot be accidentally erased.

A total of 3 ICs were developed to provide repertory facilities. The sub-contractor developed 2 of these, one for SC and one for MF4 signalling, using NMOS circuitry. The main

contractor developed the third, a CMOS SC signalling IC. The NMOS versions require a secondary battery to retain the memory contents, whilst the CMOS version uses a primary battery. The batteries are housed in the battery box in the base of the telephone. Although long-life primary batteries are expected to be viable for more than 7-years life, any battery inside a telephone is clearly a disadvantage and in due course it is anticipated that repertory ICs using non-volatile memory cells which will not require a battery will be introduced.

The repertory facilities are controlled by 2 keypad buttons designated T (for transmit) and P (for programme). Their use is best understood by considering the operating procedure for both direct exchange lines (DELs) and PABX extensions.

DEL Operating Procedure

This is summarized in Table 1. It can be seen that the P button is used only when storing telephone numbers. The T button is used to access stores.

When storing a number in one of the 10 repertory stores, the P button has to be held down for the entire duration of the storage keying operation. This is purposefully made a two-handed operation to provide a measure of security against accidental overwriting. This complexity of operation is acceptable because the reprogramming of stores is usually an infrequently performed operation. Calling a stored number either from one of the repertory stores or from the repeat-last-number store is a two-button operation; namely, T followed by the keypad button corresponding to the number associated with the repertory store or by T again to access the repeat-last-number store. The user then waits for the telephone to signal the selected number to line, and during this time the keypad is rendered inoperative. The MF4 version signals at a rate of about 7 digits/s, which is about 10 times faster than the SC version.

PABX Extension Operating Procedure

PABX extension users make calls either to other extensions on the PABX or to external lines. Extension-to-extension calls are straightforward and the procedure is identical to the DEL operation. The PABX users operating procedure is shown in Table 2. External calls use the public exchange number prefixed by one (or two or three) access digits, which may be interspersed with second (and subsequent) dial tones. It is the problem of handling the extra dial tones which complicates the procedure. This complication is best illustrated by considering the example of a user who has manually keyed a public exchange number, say 246 8091, prefixed by an access digit, say 7. The repeat-last-number store now contains 7 246 8091. The user may decide to make a repeat

TABLE 1
User's Operating Procedure (Direct Exchange Line)

To make an ordinary manual call	Lift handset	Key telephone number	Wait for connexion		
To store a telephone number in store [d]	Lift handset	Press and hold down [P] button	Key digit [d]	Key telephone number	Release [P] button
To call the telephone number in store [d]	Lift handset	Key digit [T]	Key digit [d]	Wait for connexion	
To repeat last manually keyed number	Lift handset	Key digit [T]	Key digit [T]	Wait for connexion	

Notes: 1. Stores can only be overwritten, not erased.
 2. The symbol [d] signifies any one of the 10 digits 0-9 on the keypad. The symbols [P] and [T] signify the P and T buttons respectively.
 3. This procedure also applies to PBX installations with no wait for second dial tone—telephone numbers are stored complete with the access digit(s) prefix.
 4. The term lift handset assumes dial tone is then obtained before any button is pressed (except when storing a number).

TABLE 2
User's Operating Procedure (PABX Extension)

To make an ordinary manual call	Lift handset	Key access digit(s)	Wait for final dial tone	Key telephone number	Wait for connexion	
To call an extension	Lift handset	Key extension number	Wait for connexion			
To store a telephone number in store [d]	Lift handset	Press and hold down [P] button	Key digit [d]	Key telephone number	Release [P] button	
To store an extension number in store [d]	Lift handset	Press and hold down [P] button	Key digit [d]	Key extension number	Release [P] button	
To call the telephone number in store [d]	Lift handset	Key access digit(s)	Wait for final dial tone	Key digit [T]	Key digit [d]	Wait for connexion
To call the extension number in store [d]	Lift handset	Key digit [T]	Key digit [d]	Wait for connexion		
To repeat last manually keyed number (ordinary call)	Lift handset	Key access digit(s)	Wait for final dial tone	Key digit [T]	Key digit [T]	Wait for connexion
To repeat last manually keyed number (extension call)	Lift handset	Key digit [T]	Key digit [T]	Wait for connexion		

Notes: 1. Stores can only be overwritten, not erased.

2. The symbol [d] signifies any one of the 10 digits 0-9 on the keypad. The symbols [P] and [T] signify the P and T buttons respectively.

3. The term *telephone number* means the full STD number, but excludes any access digit(s) prefix.

4. The term *lift handset* assumes dial tone is then obtained before any button is pressed (except when storing a number).

attempt at this number by pressing T twice. The PABX requires a pause in keying after the 7 has been sent in order to return external dial tone. If the telephone were to simply pulse out the entire number (including access digit) without pause, it is likely that the digit 2 would be lost, and the call misrouted. Various attempts have been made to overcome this problem, including the ability to programme in pauses or to remember access digits in an access-digit store. However, these solutions have disadvantages and were not used in the Ambassador.

The procedure adopted for the Ambassador requires the user to obtain the final dial tone manually before invoking the repeat-last-number facility. In the above example the user keys 7, waits for *dial tone*, and then keys TT. This causes the telephone to start signalling from the second digit (in this case the 2); that is, the IC is designed to skip over the 7 in the store. This operation can be understood by considering a cursor that points to the position in the store, from which the next digit is to be sent. When the handset is lifted, the cursor is automatically reset to store-position 1 (containing the access digit 7 in the example). The user keys a digit (7 in the example) and the cursor is incremented to store-position 2. The user then presses TT and the content of the store, starting at the position where the cursor is pointing, is sent to line. The repeat-last-number store is not overwritten until the user manually keys 4 digits, thus up to 3 access digits can be accepted.

The use of the cursor has a number of important advantages. Since the telephone can handle numbers in the repeat-last-number store with or without an access-digit prefix, no engineering modification is needed on installation to discriminate between PABX and non-PABX usage, as has previously been the case. Also, the user is spared the chore of keying in pauses when making a call, or programming in access digits and pauses in the repertory stores. No extra PAUSE button is required on the keypad. Moreover, there is now an increasing number of PABX installations where it is not necessary to

obtain a second dial tone. The Ambassador procedure accommodates these installations without modification and the user benefits from a slightly simplified operating procedure in addition to a faster call set-up time.

CONCLUSIONS

This article has described the joint BT/British Industry development of a new keypad and of new signalling circuitry. The keypad design offers many advantages over older designs; in particular, significant improvements have been made in reliability, cost, size and ergonomic acceptability. However, further developments using the traditional techniques of return springs, metal contacts and plastic plungers etc. would not yield significant improvements; future designs of keypad will employ new materials and manufacturing processes. The signalling circuitry is also approaching an optimum in terms of cost reliability and component count. Significant improvements will be made in the future by combining signalling and transmission circuitry on a single IC.

ACKNOWLEDGEMENTS

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The authors wish to thank their colleagues in BT and in Industry for their assistance and advice in the preparation of this article.

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INMARSAT—A New Era of Satellite Communications for Shipping

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This article describes the events that led up to the formation of the International Maritime Satellite Organization, which will take over responsibility for the provision of maritime satellite communications in February 1982. The system operation and the services provided are also described, together with details of how they differ from those of the existing system which it will replace.

INTRODUCTION

The initial phase of the maritime satellite communication era, which began with the introduction of the USA's maritime satellite (MARISAT) system in 1976, is now drawing to a close. The MARISAT system gave the world's shipping fleets the opportunity to supplement the traditional medium-frequency (MF) and high-frequency (HF) radio communications with the higher quality and reliability of service achievable with a satellite system.

Beginning in February 1982, the International Maritime Satellite (INMARSAT) Organization, which came into being in July 1979, will take over responsibility for providing maritime satellite communication services. One of the first tasks of INMARSAT will be to replace the 3 ageing MARI-SAT satellites with 2 new designs, known as *MARECS*, and *INTELSAT-MCS*, capable of providing for the growth of maritime satellite communications into the late-1980s.

PRE-INMARSAT MARITIME MOBILE SATELLITE SYSTEMS

In October 1977, an article appearing in the *Journal* entitled *Developments in Maritime Satellite Communications*¹ described 2 satellite systems: the USA's MARISAT, and the European Space Agency's (ESA's) MAROTS. At that time, the MARI-SAT system was in operation, whilst the MAROTS satellites were intended for launch in 1978.

MARISAT System

The MARISAT satellites (see Fig. 1) were primarily intended for use by the US Navy, but they were also able to provide additional limited capacity for commercial use. By February 1981, over 500 merchant ships had been commissioned to operate through the system.

It was during the period of the international effort to create INMARSAT that the MARISAT Joint Venture emerged. In the late-1960s and the early-1970s, the Communications Satellite Corporation (COMSAT), a private US Corporation authorized by the US Government to provide satellite communications, was exploring the possibility of establishing a satellite system to meet the maritime communication requirements of the US Navy. In 1973, COMSAT entered into a contract with the US Navy to provide communication services through satellites that would also have some capacity to provide services to the commercial shipping and offshore industries. The 3 satellites were launched in 1976, thus bringing the MARISAT system into operation.

COMSAT's wholly-owned subsidiary, Comsat General Corporation, owns about an 86% interest in the system, and

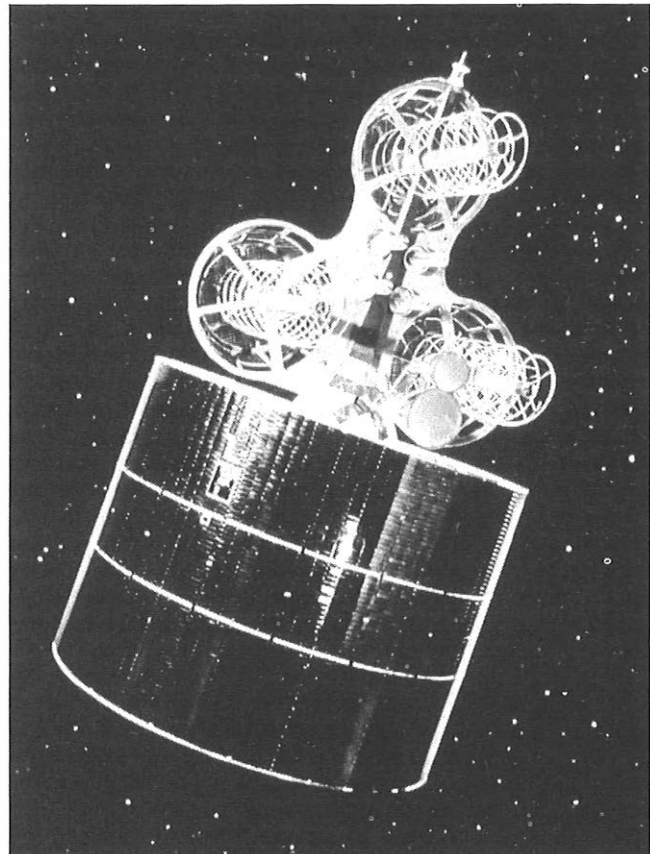


FIG. 1—The MARISAT spacecraft

is the system manager. The other participants in the MARI-SAT Joint Venture are RCA Globcom, ITT Worldcom, and Western Union International.

The shore stations serving each satellite are in the USA at Southbury, Connecticut (Atlantic Ocean satellite) and Santa Paula, California (Pacific Ocean satellite), and in Japan at Yamaguchi (Indian Ocean satellite). These earth stations have an antenna diameter of 13 m and are used to provide the feeder links in the 6 GHz and 4 GHz bands between each shore station and its satellite. Ships communicate with the satellites in the 1.5 GHz and 1.6 GHz bands; the MARISAT transponders translate the 6 GHz band to the 1.5 GHz band in the shore-to-ship direction, and the 1.6 GHz band to the 4 GHz band in the return direction.

The overall system capacity is constrained, however, by the shore-to-ship transponder, which is severely power limited. An irregular Babcock-type² channel plan has been adopted to

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minimize the effects of intermodulation products by making full use of the 4 MHz bandwidth, but this results in a restricted simultaneous voice capacity of only around 8 channels. Unlike the telephony carriers which operate in a single-channel-per-carrier/frequency-division multiple access (SCPC/FDMA) mode using narrow-band frequency modulation (NBFM) with companders, Telex operation uses time-division multiplex (TDM). In the shore-to-ship direction, a 1.2 kbit/s TDM carrier provides 22 channels per shore station, with one channel reserved for assignment purposes. In the ship-to-shore direction, the Telex information is transmitted on a time-division multiple access (TDMA) channel at 4.8 kbit/s, a separate 4.8 kbit/s channel being used for random access and signalling.

MAROTS System

The ESA's MAROTS satellite was originally conceived as part of an experimental system to acquire pre-operational experience, and essentially comprised 2 basic modules: a maritime communication module, and a service module based on the ESA's Orbital Test Satellite (OTS). Subsequently, the ESA offered the MAROTS satellite for operational use. The overall characteristics of the MAROTS system, which were defined within the CEPT† organization in co-operation with the ESA, were somewhat different from those of the MARISAT system. Two important differences were that the MAROTS system adopted TDMA for Telex and signalling in

† CEPT—Conference of European Postal and Telecommunication Administrations

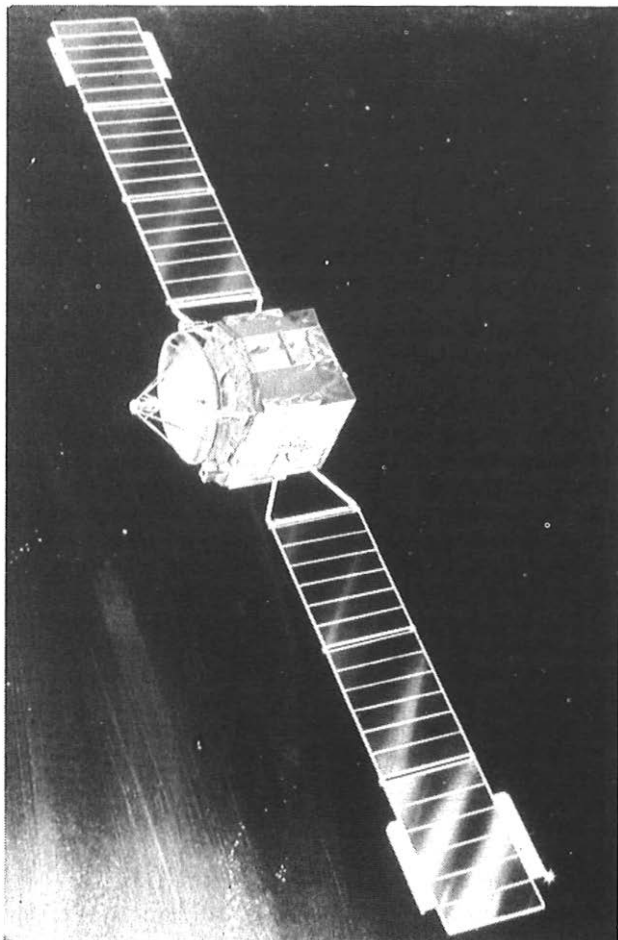


Fig. 2—The MARECS spacecraft

both ship-to-shore and shore-to-ship directions of transmission, and the feeder links were to operate in the 14 GHz and 11 GHz bands.

However, the MAROTS system was never to become a reality. With the aim of making the ESA maritime satellites available as part of a world-wide service which could be integrated with the operational MARISAT system, the MAROTS satellites were modified into MARECS satellites with feeder links in the 6 GHz and 4 GHz bands. These modified satellites are based on the ESA's European Communication Satellite (ECS) service module and, unlike the MAROTS satellites, are able to remain fully operational during periods of eclipse of the sun. The MARECS spacecraft is shown in Fig. 2.

THE INMARSAT ORGANIZATION

The origins of INMARSAT can be traced back to 1966, when the sub-committee on radiocommunications of the Intergovernmental Maritime Consultative Organization (IMCO) expressed an interest in improving communications to ships, with particular emphasis on safety and distress—a primary concern of IMCO. The need to consider satellite communications was primarily motivated by the problems associated with ionospheric disturbances, which can often lead to delays of hours or even days when using traditional MF and HF radiocommunications. A panel of experts was established to consider the technical, operational, administrative and constitutional aspects of introducing satellite communications to the maritime world.

After the IMCO panel of experts had completed its work, IMCO convened the International Conference on the Establishment of an International Maritime Satellite Organization, which held 3 sessions between April 1975 and September 1976 to negotiate suitable agreements.

The Conference adopted 2 instruments: a Convention, to be signed by governments; and an Operating Agreement, to be signed by governments or government-designated public or private entities. This approach was similar to that followed in the formation of the International Telecommunications Satellite (INTELSAT) Organization. Negotiations were completed in September 1976, and the INMARSAT Convention and the associated Operating Agreements were opened for signature. Although there are certain differences, many similarities exist between both the provisions of the INTELSAT and INMARSAT agreements and the organizations themselves.

The International Maritime Satellite Organization finally became a reality in July 1979 and, by April 1981, 36 states were signatories to the Convention. The largest shareholder is the USA with a holding of about 23.4%. The next 4 largest shareholders are the USSR (14.1%), the UK (9.9%), Norway (7.9%) and Japan (7%). After the INMARSAT system is established, each member's investment share in the organization will be adjusted periodically to reflect their proportionate use of the system. The investment share determines voting strength in the INMARSAT Council, as well as the extent of a member's financial commitment to the organization. The organizational structure consists of an Assembly, made up of representatives of governments that have acceded to the INMARSAT Convention, a Council, currently consisting of 24 representatives of signatories to the Operating Agreement, and a Directorate. Voting of Council members is weighted on the basis of the investment share, or shares, represented by each member. The Assembly, which normally meets biennially, is primarily responsible for considering and reviewing the activities, purposes, policy and objectives of the organization, and for making recommendations to the Council. The Council, which meets at least 3 times annually, is responsible for developing and adopting the necessary programmes and arrangements for the establishment and operation of the

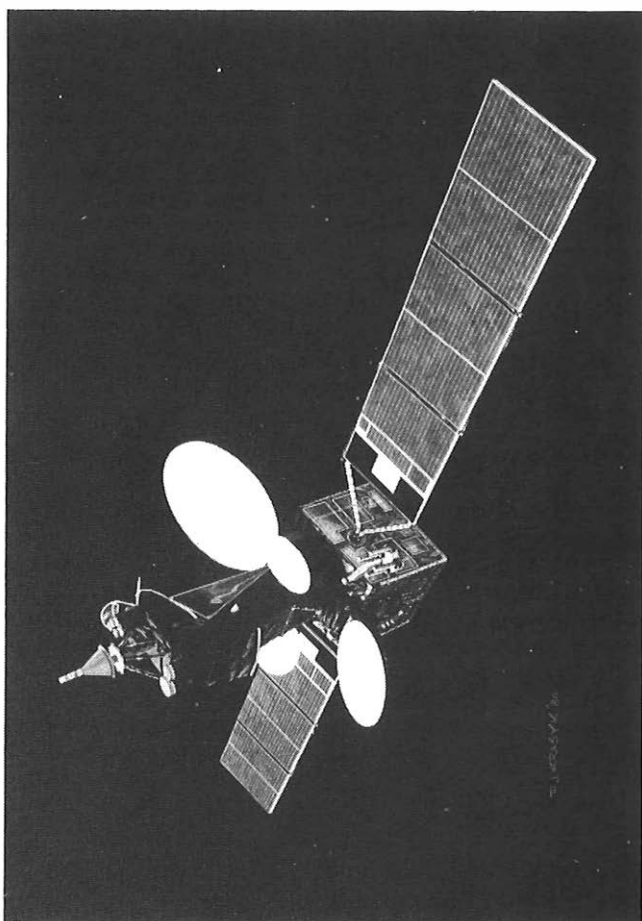
INMARSAT satellite system facilities. In addition, the Council has a Finance Committee which meets twice a year, and an Advisory Committee on Technical and Operational Matters (ACTOM) which meets between Council sessions.

SYSTEM OPERATION AND SERVICES

The first major task of INMARSAT has been to procure the follow-on space segment (that is, satellites and control stations) for when the MARISAT satellites reach their end of life around the early-1980s and contracts worth about £75M have been placed for the lease of satellite capacity over the period 1982 to 1989. The contracts have been awarded to ESA, INTELSAT and the Comsat General Corporation. ESA will provide 2 dedicated satellites, MARECS A and B, and the INTELSAT organization will provide 3 maritime communications sub-system (MCS) packages (MCS 1, 2 and 3) on the later flight models of the INTELSAT V satellites, whilst Comsat General will continue to provide end-of-life capacity on the Pacific Ocean region MARISAT satellite. In addition, INMARSAT intends to lease end-of-life capacity on the Atlantic and Indian Ocean MARISAT satellites for a limited period as a contingency measure during the initial period. The INTELSAT V spacecraft incorporating an MCS is shown in Fig. 3.

System Characteristics

To ensure continuity of services, and keep costs to both established coast earth stations and ship terminals to a minimum in the transition period from MARISAT to



Note: The MCS antennae can be seen on a corner of the spacecraft adjacent to the solar panel supports

FIG. 3—The INTELSAT V spacecraft with the MCS

TABLE 1
MARISAT/INMARSAT System Characteristics

Feature	System Characteristics
Telephony	Companded NBFM using SCPC/FDMA operation. Threshold extension demodulators permitting operation at 52-53 dBHz C/N ₀ in a 28 kHz radio-frequency bandwidth resulting in a subjectively-equivalent noise of 25 000 pWop.
Telex Shore-to-ship	22 Telex channels on a single TDM carrier at 1.2 kbit/s data rate, 2-phase coherent phase-shift keying (PSK)
Ship-to-shore	22 Telex channels carried by a single TDMA carrier at 4.8 kbit/s data rate, 2-phase coherent PSK
Coast Earth Station	Around 13 m diameter, G/T = 32.0 dB/K. Typical EIRP of 60 dBW (voice), 57 dBW (TDM)
Ship Earth Station	Fully stabilized antenna, diameter approximately 1.2 m, G/T = -4 dB/K, protected from weather by radome, EIRP of 37 dBW

C/N₀: Carrier-to-noise-density ratio
G/T: Gain/noise sensitivity
EIRP: Effective isotropic radiated power

INMARSAT, the basic modulation and multiple-access methods have been retained. The earlier article¹ gave a full description of the modulation, multiple-access methods, channel assignment and signalling procedures of MARISAT. The essential characteristics are reproduced in Table 1.

Apart from the telephony and Telex services detailed, it is also possible to use medium-speed data (2.4 kbit/s), and facsimile via the voice channels, and high-speed data at 56 kbit/s, the latter in the ship-to-shore direction only.

Perhaps the main difference from the MARISAT system that will result from the introduction of the INMARSAT system will be the ability to cater for more than one coast earth station in each ocean region. In the MARISAT system, customer access is via one of the 3 MARISAT coast earth stations in the USA and Japan, and the resulting high tariffs (which include the add-on charges to the USA or Japan) have discouraged many potential customers. With the INMARSAT system, ships will be able to make calls to and from any destination using the most appropriate INMARSAT coast earth station, and thus avoid the add-on charges.

Ship Earth Stations

The ship earth stations for use with the INMARSAT system will be identical in their principal characteristics to those used with the MARISAT system. Thus, ships operating to the MARISAT system will be able to transfer to the INMARSAT system without any changes being required, although some modification will be necessary to make full use of the INMARSAT facilities (for example, the operation to any one of a number of coast earth stations in each region).

The ship earth station consists of an antenna, a low-noise receiver and an amplifier (see Fig. 4) mounted high on the ship's superstructure, and protected by a radome (see Fig. 5), together with a below-decks module containing a processor-controlled terminal equipment and control system (see Fig. 6).

Network Co-ordination Stations

The expansion to more than one coast earth station per ocean area necessitates the introduction of 3 network co-ordination stations (NCS) into the network, one for each ocean area. The 3 NCSs are to be at Southbury, USA (Atlantic

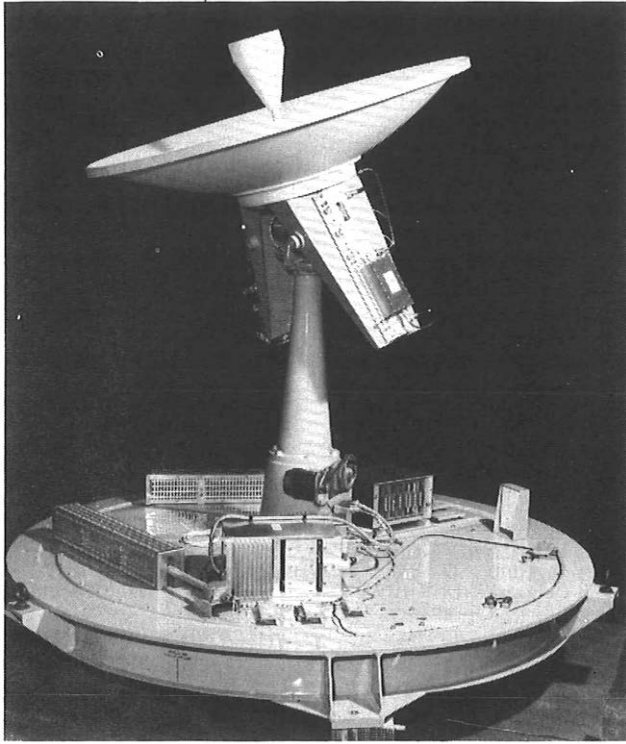


FIG. 4—1.2 m antenna and low-noise receiver
(Photograph by courtesy of The Marconi Company Ltd.)

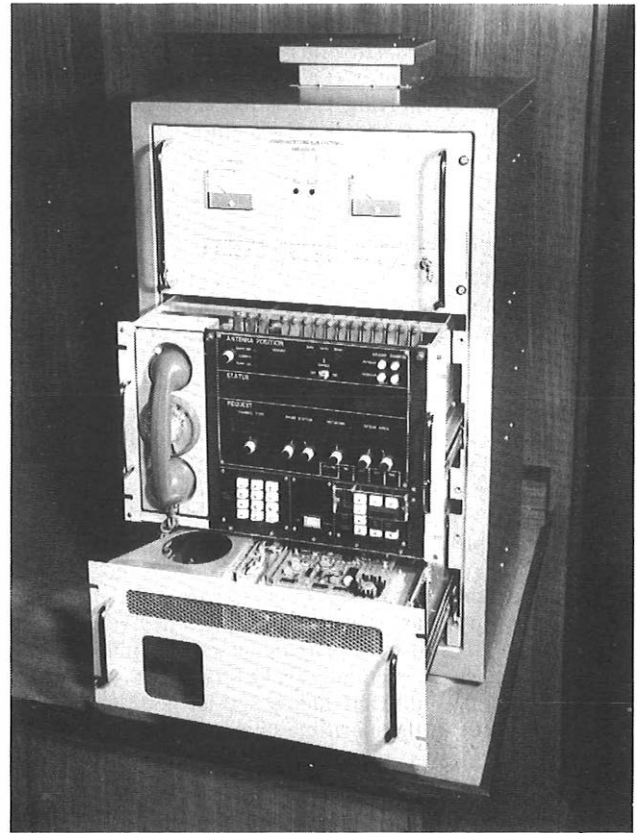


FIG. 6—Typical below-decks terminal equipment
(Photograph by courtesy of The Marconi Company Ltd.)

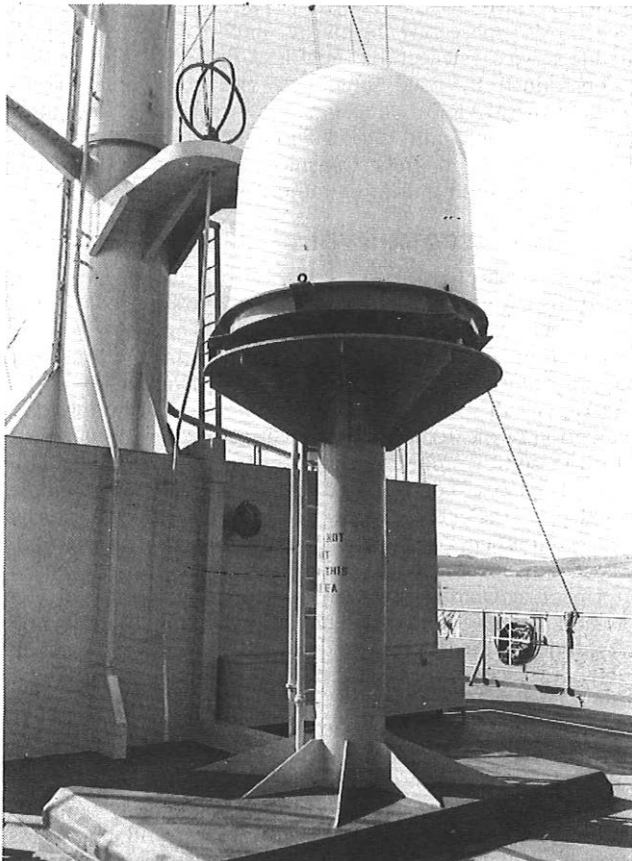


FIG. 5—Typical antenna installation showing radome weather protection
(Photograph by courtesy of The Marconi Company Ltd.)

Ocean region), Yamaguchi, Japan (Indian Ocean region) and Ibaraki, Japan (Pacific Ocean region). Each standard coast earth station will transmit its own unique TDM carrier on a frequency pre-assigned by INMARSAT whilst the station fulfilling the role of the NCS will transmit a *common* TDM carrier. The essential co-ordination functions that the NCS will perform in the case of shore originated calls are:

(a) Accepting Telex assignment messages from other coast earth stations and broadcasting them to ship earth stations on the common TDM carrier. This requires the NCS to receive all TDM carriers from standard coast earth stations in the network.

(b) Accepting telephone channel *request-for-assignment* messages from all standard coast earth stations in the network and making telephone channel assignments via the common TDM carrier.

(c) Maintaining a telephone channel-activity list which indicates which channels are busy as well as the coast earth station and ship earth station using each channel.

(d) Clearing a voice call in progress if necessary to service an SOS priority request.

(e) Maintaining a record of all channel usage for network analysis purposes.

These functions require that the common TDM carrier is always monitored by the other standard coast earth stations, and by idle ship earth stations. The ships also continue to monitor the common TDM carrier during voice calls, but not during Telex calls when they are tuned to the appropriate coast earth station TDM carrier. In the case of ship-originated calls, the ship requiring service will apply directly via the ship-to-shore *random access* carrier to the selected coast earth station. The coast earth station will then contact the NCS using its own TDM carrier, and thenceforth the same procedure as for shore-originated calls will ensue.

Operational Control Centre

Operationally, the INMARSAT system will be run from the operational control centre (OCC) at INMARSAT headquarters, London. Reporting directly to the OCC will be the 3 aforementioned NCSs, and the 3 Satellite Control Centres (SCCs): COMSAT, and INTELSAT from Washington, USA; and ESA from Darmstadt, West Germany.

Frequency Spectrum Requirements

Looking towards the future, it seems likely that INMARSAT will require more frequency spectrum to achieve its aims. At the World Administrative Radio Conference 1979, Maritime Mobile Satellite allocations in the 1.5/1.6 GHz bands totalled 15 MHz and 20 MHz in the forward and return direction respectively, and forecasting traffic demand from current growth suggests that all this bandwidth may be required by the year 2000. Reflecting these allocations in the shore-to-satellite feeder links means a corresponding requirement in the 6/4 GHz bands.

However, a particular problem for the maritime mobile satellite service results from the fact that it does not possess any exclusive rights to the spectrum used for its feeder links at 6/4 GHz, but must share the allocation with the fixed satellite service. Hence, it is likely that frequency co-ordination with fixed satellite services, essentially INTELSAT, at 6/4 GHz will become increasingly difficult unless special consideration is given to the needs of the maritime satellite service.

SPACE SEGMENT

The new satellites, MARECS A and B, and INTELSAT V-MCS 1, 2 and 3, will start to be introduced into the INMARSAT network from the beginning of 1982 as the MARISAT satellites approach the end of their life. The intended space segment configuration, and the dates that the satellites are expected to become available for maritime use, are shown in Table 2.

A major limitation of MARISAT satellites is their capacity of approximately 8 voice circuits, the demand for which has already been exceeded in the Atlantic Ocean region and Indian Ocean region. The new satellites have an increased capacity of about 30 and 40 voice-circuits for the INTELSAT V-MCS and MARECS respectively, resulting mainly from the increased power available, and reduced intermodulation impairments. This should be adequate until the late-1980s in the Atlantic Ocean region and Indian Ocean region, and until the early-1990s in the Pacific Ocean region.

Table 3 presents the important characteristics of each satellite.

TABLE 2
INMARSAT Space Segment Configuration

Ocean Region	Satellite and Orbital Location	Expected Availability
Atlantic	MARISAT (15°W)	Existing
	MARECS A (26°W)	March 1982
	INTELSAT V-MCS 2 (21.5°W)	August 1982
Indian	MARISAT (73°E)	Existing
	INTELSAT V-MCS 1 (63°E)	August 1982
	INTELSAT V-MCS 3 (60/66°E)	January 1982
Pacific	MARISAT (176.5°E)	Existing
	MARECS B (177.5°E)	July 1982

TABLE 3
Satellite Characteristics

	MARISAT	MARECS	INTELSAT-MCS
Configuration	Shared with US Navy services	Dedicated maritime satellite	Maritime package on INTELSAT V fixed satellite services spacecraft
Station Keeping	East-West ±0.5° Inclination ±3°	East-West ±0.2° Inclination ±3°	East-West ±0.1° Inclination ±0.1°
Stabilization	Spin	3-axis	3-axis
Receive G/T Shore-to-Ship Ship-to-Shore	-21 dB/K -17.5 dB/K	-17 dB/K -12.1 dB/K	-18.6 dB/K -15 dB/K
Total EIRP Shore-to-Ship Ship-to-Shore	27 dBW 18.8 dBW	34.2 dBW 14.5 dBW	32.6 dBW 20 dBW
Bandwidth	4 MHz	5 MHz	7.5 MHz
Approximate Voice-Channel Capacity Shore-to-Ship Ship-to-Shore	8 14	40 50	30 100

The essential difference between the 2 new types of spacecraft is that the MARECS satellites are dedicated for maritime use and can be placed at any point on the geostationary orbit, subject to visibility and interference constraints, whereas the INTELSAT-MCS is a maritime package as part of an INTELSAT spacecraft primarily intended for the fixed satellite services; hence, the INTELSAT-MCS orbit position is constrained by fixed satellite service considerations. In addition, the MARECS ship-to-shore transponder contains a narrowband high-gain repeater intended to accommodate search-and-rescue distress transmissions at 1.6 GHz from emergency position indicating radio beacons (EPIRBs).

BRITISH TELECOM INVOLVEMENT

As stated earlier, the UK has a 9.9% share in INMARSAT, and British Telecom (BT) is the entity designated by the Government to represent this UK interest. The first UK coast earth station is to be at Goonhilly (the fifth ground station at that site) and will operate using a 14.2 m antenna to the Atlantic Ocean region satellite. The contract for supply and installation of the aerial and radio equipment has been placed with Marconi Communications Systems Ltd., whilst the associated access control and signalling equipment will be provided by the Digital Communications Corporation. The installation is scheduled to be ready for service in May 1982.

To arrange access for the other ocean areas, BT signed an agreement in October 1980 with the Nordic Group of telecommunications administrations (Denmark, Finland, Norway and Sweden) who are constructing a coast earth station at Eik in Norway to work to an INMARSAT satellite that will be located over the Indian ocean. This agreement will enable BT and the Nordic administrations to use each other's stations to gain access to both the Atlantic and Indian Ocean regions. BT and the Nordic administrations have also signed a memorandum of understanding with the Telecommunications Administration of Singapore, whose coast earth station will give access to and from the Pacific Ocean region. Under these agreements, administrations handle each other's traffic, and INMARSAT users operating to and from the UK will not incur the large international add-on charges at present experienced by MARISAT users.

FUTURE DEVELOPMENTS

For some maritime applications, it is already clear that the established single Standard A -4 dB/K G/T ship terminal (see Figs. 4, 5 and 6) is not optimum, or simply cannot cope with the services required. Studies dating back to the IMCO panel of experts have considered 4 standard terminals, and their designations have been retained as nominal classes (see Table 4).

The next class of ship earth station to be established, largely as a result of the anticipated demand for reliable communications to the offshore oil industry, will probably be the Standard D type. If a single user requires, for example, 5 or more simultaneous voice circuits from one location, the advantages of a single large terminal soon become apparent. Firstly, on cost alone, a single Standard D terminal to provide a multi-channel service (as against the provision of multiple Standard A terminals) must become more economic at some point. Secondly, such a Standard D terminal would make more economic use of the INMARSAT space segment. In the power-limited shore-to-ship direction, advantages can be taken of the high-gain Standard D antenna by transmitting around 10 voice carriers within the satellite power of a regular voice carrier destined for a Standard A terminal.

A terminal which has attracted interest over the years is the Standard B ship earth station; the potential market for a small low-price terminal suitable for mounting on smaller vessels, and able to provide voice and Telex, is considerable. However, if the same channel performance standards were required with these terminals, then the demand on satellite power would be greatly increased, and the first generation of INMARSAT satellites would only be able to support a few of these terminals at any one time. In this context, much research has been done into speech performance using modulation techniques that require a carrier-to-noise density of only around 43 dBHz; one very promising technique employs vocoders which are able to operate at 2.4 kbit/s with a bit error rate approaching 1%.

However, the acceptability of synthetic speech, particularly if carried through the public switched telephone network needs further study. The second aspect of Standard B ship earth stations that has attracted much research is concerned with the problems of multipath fading over sea paths which becomes more acute with reduction in antenna gain.

Considerable interest is also being shown in Telex-only Standard C ship earth stations, which suffer from difficulties similar to those described for the Standard B terminal associated with satellite power limitations and even more acute multipath fading.

The characteristics of antennae with gains approaching omnidirectional are of great interest to safety and distress authorities, who wish to standardize on the characteristics of

† CCIR—International Radio Consultative Committee

TABLE 4
Nominal Ship Earth Station Classes

	Standard A	Standard B	Standard C	Standard D
EIRP	37 dBW	29 dBW	19 dBW	37–47 dBW
G/T	-4 dB/K	-12 dB/K	-19 dB/K	$+5$ dB/K
Antenna Gain Diameter (parabolic)	23 dB 1.2 m	15 dB 0.5 m	8 dB (non-parabolic)	32 dB 3 m
Services	Voice Telex	Reduced-quality voice Telex	Telex only	Multiple voice Multiple Telex High-speed data

Note: Standard A ship earth station is the current INMARSAT standard

an EPIRB. INMARSAT has already agreed that organizations concerned with EPIRBs may have free use of the space segment to conduct tests, and the CCIR† is preparing a co-ordinated test programme. In this respect, INMARSAT has established co-ordination with IMCO on the future global maritime distress and safety systems programme.

CONCLUSIONS

The formation of INMARSAT has enabled the limited MARISAT satellite network to be developed into a fully international service adequate to meet most maritime radio-communication requirements into the 1990s. However, much of the foregoing discussion has been related to potential limitations of the first generation INMARSAT space segment. Looking to the future, although there will be continuity of service for current users, the next generation of INMARSAT satellites will offer greater opportunities. In particular, the use of satellite spot beams and increased satellite powers could allow for not only greater channel capacity, but a host of new applications and services.

ACKNOWLEDGEMENTS

The author wishes to thank his colleagues in British Telecom and in INMARSAT for their assistance in the preparation of this article.

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Wire Wrapping of Aluminium Conductors

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Wire wrapping is used extensively in the telecommunications industry for the termination of solid copper conductors. With the increasing use of aluminium conductors in the British Telecom local cable network, it has not proved possible to produce wire wrap terminations using the same techniques and equipment. This article describes the research carried out to perfect a system to wire wrap aluminium conductors.

INTRODUCTION

The technique of wire wrapping has become a standard method in the electronics industry for terminating copper wire. British Telecom (BT) first adopted a copper wire-wrap system for use on exchange internal wiring, and its use was subsequently extended to the termination of external copper cables to the main distribution frame (MDF). Recently, aluminium conductor cable has been introduced into the local underground network¹. Therefore, there is an increasing demand to terminate aluminium conductors directly on the MDF.

At present it is impractical to terminate aluminium wire by conventional methods such as soldering, wrapping or screw connexion. Connexion is achieved by joining the aluminium to a length of copper wire (or tail). Termination can then be carried out using standard (copper) wire-wrapping techniques, with the aluminium-to-copper joint being made using existing crimp-type connectors. The cost advantage to be gained when directly terminating aluminium is significant, compared with the cost of the crimp connexion and length of copper wire.

BT Research Department (BTRD) was requested to investigate any techniques that could enable direct termination of aluminium on the MDF. Preliminary examination suggested that a cost-effective solution could be achieved by development of the present wire-wrapping techniques. This would require the re-design of the (copper) wrapping heads, but the minimum of modification to the existing Jacks Test 37 (JT 37) block terminal (see Fig. 1). This article describes the development and evaluation of an aluminium wire-wrap system for use on these MDF block terminals.

TERMINAL AND STANDARD TOOLING

Wire wrapping is a form of electrical termination that is used extensively in the telecommunications industry. Currently, its use is restricted to the termination of copper conductors, where wire-wrap systems have proved consistently reliable over a long period of time². The technique was introduced primarily to improve the efficiency and reliability of conductor termination. Prior to the introduction of wire wrapping, connexion was achieved either by screw terminal or solder joints, but these methods did not permit the high termination density required by the telecommunications industry. Furthermore, they were time consuming, and dependent on individual operator performance. Wire wrapping, however, is a high-speed technique, which provides high termination density, and is less sensitive to operator variability.

Electrical connexion by wire wrapping is achieved by deforming a conductor around a rectangular-section pin, so that electrical contact is established at the pin corners. Normally a completed wrap consists of a minimum of 6 turns of conductor, arranged in the form of a helix along the pin (see Fig. 2). This number of turns ensures both a robust joint and a reliable electrical connexion. Wire-wrap pins are available in a variety of shapes and sizes. For example, in

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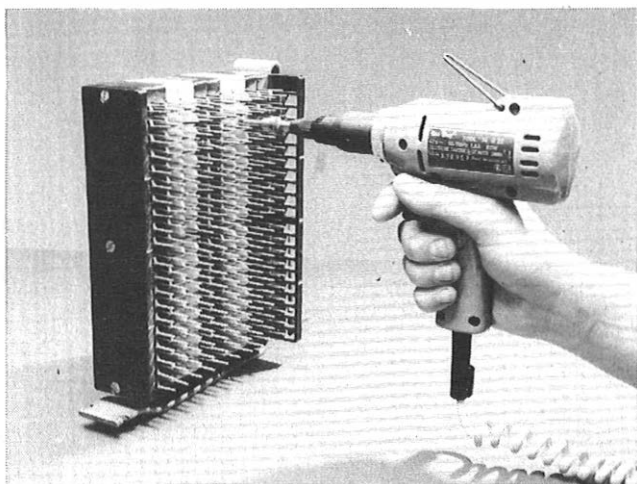


FIG. 1—Wire-wrap gun in position on jacks test terminating unit

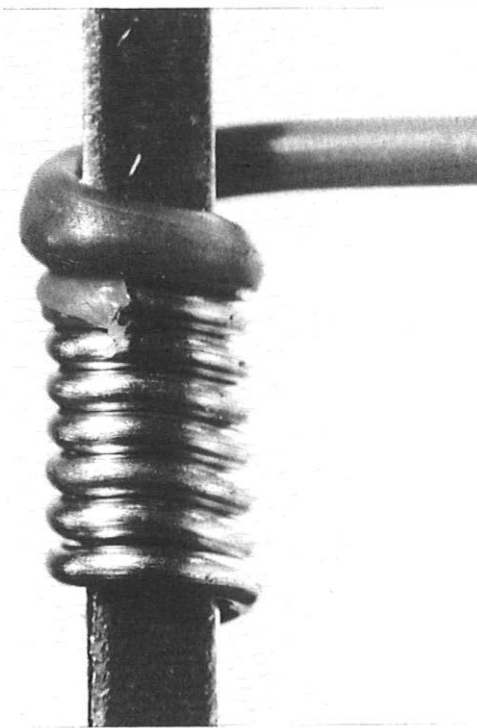


FIG. 2—Wire-wrap termination

telecommunications work, the range of pin-section sizes varies from 0.7 mm diagonal micro-wrapping up to 1.8 mm diagonal. The main application in BT is for the standard range of pins, which have a 1.8 mm diagonal. These pins are generally rectangular, with a section size ratio varying from 1:1 to 2:1. They can be manufactured in various materials such as brass, nickel silver or phosphor bronze. The completed pins are usually plated with one of a variety of electrical contact materials such as gold, silver or tin³.

Wire wrapping is normally carried out using a hand-held wire-wrapping gun (see Fig. 1), which can be hand powered, air driven or electrically powered. The powered versions consume 80 W and operate at 4000 rev/min. BT normally uses a version powered electrically from the standard 50 V supply available in exchanges. High-speed guns are used so that termination can be completed in a minimum amount of time. Furthermore, a fast wrap ensures continuous tension in the conductor and minimizes the time available for the operator inadvertently to move the gun and so damage the joint.

Guns are supplied separately from the wrapping heads, enabling the selection of a suitable head to be made from the large range of heads available to accommodate the variety of conductor and pin sizes. Heads are attached to the gun by means of a standard collet arrangement. The heads normally used in industry are of the *cut-strip-and-wrap* variety: the wrapping operation proceeds by initially cutting the wire to length, and simultaneously stripping and wrapping the conductor. A typical head of this type is shown in Fig. 3.

This type of head is used in BT for all wire wrapping operations except where cellular polyethylene insulation is used. This is the case with the current designs of external cable. This insulation has proved difficult to strip, but a satisfactory connexion can be achieved by wrapping the wire with the insulation in place, the connexion being established by the sharp corners of the pin perforating the insulation and establishing good electrical contact to the copper conductor.

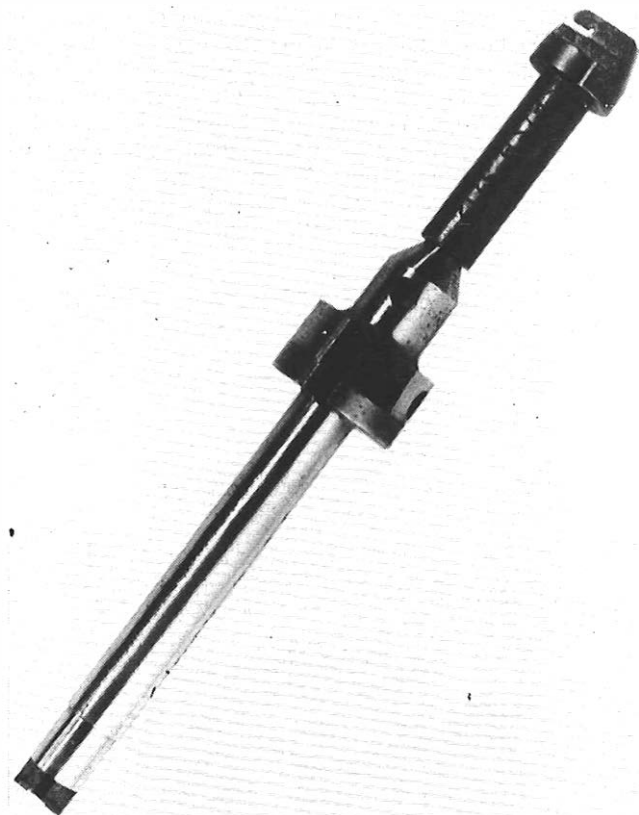


FIG. 3—Wire-wrap head in cutter/holder

THEORY OF WIRE WRAPPING

The theory of wire wrapping is based on the ability of 2 metallic surfaces to form a good electrical contact when forced together. Sufficient initial wire tension must be applied when wrapping the conductor around the pin so that any surface films on the wire and pin are displaced, forming a large metallic clean contact area. In practice, several turns of the conductor are required to maintain contact pressure. The first and last turns contribute little to the total contact area; for example, a 6-turn wrapped connexion on a rectangular terminal has 4 effective turns. As wrapping proceeds, the wire is forced over the post corner, so that plastic deformation occurs. This deformation occurs not only in the soft conductor, but also in the harder post. The wrapping action continues over the post corners, forming a helical wrap whilst maintaining tension in the wire and so, in the completed wrap, there are 4 contact areas per turn of conductor.

The long-term contact force is provided by residual stresses within the terminal. As the wrap progresses, the wire tension applies an axial torque to the terminal pin. This results in a residual elastic twist in the pin, which compensates in part for the long-term stress relaxation of the conductor. The wrapping action induces a residual elastic tension in the wire, which further contributes to the total residual stress of the system. There is also a component of residual compressive stress around the points of contact. Finally, there is an elastic compressive stress in the wrapping pin. The combination of these residual stored stresses maintains the contact force as long-term creep and stress relaxation takes place⁴. It is essential that these residual stresses are sufficient to maintain contact forces for the required service life of the terminal.

To ensure good service life for this type of connexion, the electrical resistance must remain constant over a long period of time, and this requires that the contact area remains substantially constant. The contact force can decay over the service life without increasing joint resistance. The resistance increases only when the force is reduced to such a low value that vibration and handling cause partial separation of the contact area, allowing re-oxidation of the contact surfaces.

WIRE-WRAPPING TECHNIQUES IN CURRENT USE

Most of the wire-wrapping equipment used by BT are proprietary items which are adequate for most terminating requirements. These systems use cut-strip-and-wrap techniques. The exception being for external cable terminated on the MDF, where the conductor insulation is not compatible with the conventional tooling. This type of insulation has been introduced to improve cable conductor density and transmission performance, and also to improve cable moisture sealing. The insulation, unlike standard polyvinyl chloride, is of a cellular polyethylene form which is extremely difficult to strip. This difficulty arises not only because the insulation adheres to the conductor, but also because it tends to collapse under the stripping load and jam up in the stripping slot (see Fig. 4). The combined effect often results in premature wire breakage during wrapping.

Various attempts were made to develop a technique to remove this type of insulation during the wrapping process. None of these was successful, and it was concluded that wrapping without total insulation removal may provide the answer (a *cut-wrap* system). This problem was investigated by BT's Transmission Department which subsequently developed a suitable wrapping head for use with copper conductors. This new head incorporates a feature which forces the wire against the terminal pin in such a way that the insulation is penetrated, and contact is made. This head has proved very successful in practice.

The present situation in BT is that on the internal side, a cut-strip-and-wrap system is used. The use of a small range of copper wire sizes requires only a small range of heads. In

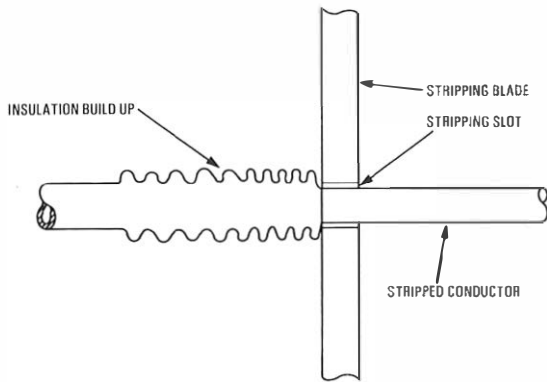


FIG. 4—Diagram of insulation build-up in conventional cut-strip-and-wrap tool

contrast, external cable termination uses a cut-and-wrap system and the variety of wire sizes requires a relatively large range of wrapping heads.

FUNDAMENTAL PROBLEMS OF TERMINATING ALUMINIUM CONDUCTORS

All of the wire terminating systems now in use were developed for use exclusively with copper conductors. Until now, in the telecommunications industry, the wrapped termination of aluminium conductors has not proved satisfactory. Primarily, problems arise because of the physical properties of the aluminium.

In comparison to copper, aluminium has inferior strength and ductility. Its surface oxidation properties are poor when compared to copper; that is, the aluminium oxide is rapidly formed in air, and has poor electrical conducting properties. In contrast, copper forms a stable low-resistance oxide when exposed to air. The difficulty of terminating aluminium is that successful penetration of the oxide must occur. Once penetrated, sufficient contact pressure must be maintained so that the mating surfaces do not separate and re-oxidize. Furthermore, the stress-relaxation properties of aluminium are inferior to those of copper. Any contact system to be used with aluminium must take account of all these factors.

The wire-wrap terminal when used on aluminium conductors has one major disadvantage; that is, the performance of a wire wrap depends on residual stored energy within the wire. The ability of aluminium to retain this stored energy is poor relative to copper. The reduction in stored energy, coupled with the poor electrical qualities of the aluminium surface, results in a more critical contact.

The requirement to terminate aluminium directly onto the MDF combines 2 problems:

- (a) the fundamental contact problems associated with aluminium conductors; and
- (b) the difficulties of removing the cellular insulation.

Termination with the existing non-strip wrap tools did not give good electrical results: examination of wraps made with the current tools showed that reliable insulation penetration had not been achieved, and also that the aluminium conductor was extensively deformed. It was evident that the relatively soft aluminium could not provide sufficient reaction to displace the insulation at the contacts, and that this resulted in poor electrical performance. These results demonstrated that successful termination of aluminium can be achieved only by completely stripping the insulation from the conductor prior to wrapping, and that difficulties of removing the cellular polyethylene would require the development of new techniques in insulation removal.

PRELIMINARY EXPERIMENTS ON WRAPPING ALUMINIUM CONDUCTORS

Initial experiments were carried out to measure the force required to remove the insulation by conventional slot or V-notch techniques. The results showed that the stripping force was slightly lower than the breaking strength of the wire. This suggested that the standard copper cut-strip-and-wrap tool could operate on aluminium, but in practice, this was proved not to be the case when trials with the standard cut-strip-and-wrap tools resulted in frequent wire breakage. It was evident that the wire was not strong enough under these wrapping conditions; the tool introduced frictional drag which resulted in increased tension to the wire, and the combination of the stripping tension and the frictional load frequently exceeded the strength of the wire.

Having established the cause of wire breakage, investigation continued to identify any modifications which might improve tool reliability. The standard tool (see Fig. 5) passes the wire through a slot which is wide enough to provide a clearance for the conductor, but restricts the passage of the insulation; the insulation is therefore held back. After passing through this slot, the conductor passes over a 90° corner to align it for wrapping on the pin. The stripping force is transmitted over this corner, inducing high frictional tension. Reduction in wire tension could be made by introducing the stripping process after it has passed over this corner. This modification was incorporated into the first BTRD redesigned head, and trial of the tool demonstrated a significant improvement over existing heads. However, as the quantity of trial terminations increased it became apparent that the occurrence of wire breakage was still too great, and that further development of the tool would be necessary.

DEVELOPMENT OF THE INSULATION SPLITTING WIRE-WRAP HEAD

It was evident from using the BTRD head that a successful wrap was frequently associated with a particular form of stripped insulation in which the insulation was longitudinally split, causing it to peel away from the conductor. High-speed cine film enabled detailed examination of the process and revealed that the insulation split was produced by local pressure as the wire passed over the 90° corner. If this effect could be enhanced, a more reliable strip might be achieved.

The development of the insulation-splitting wire-wrap tool took place over a number of stages, and the use of high-speed cine film enabled effective examination of the process at these various stages of development. It identified a number of tool

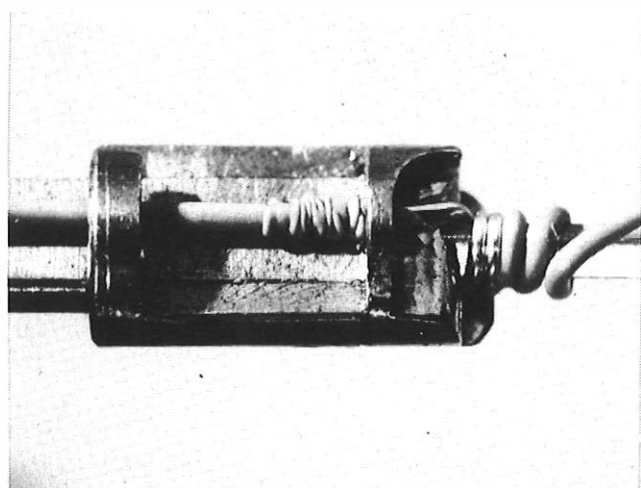


FIG. 5—Insulation build-up in conventional cut-strip-and-wrap tool

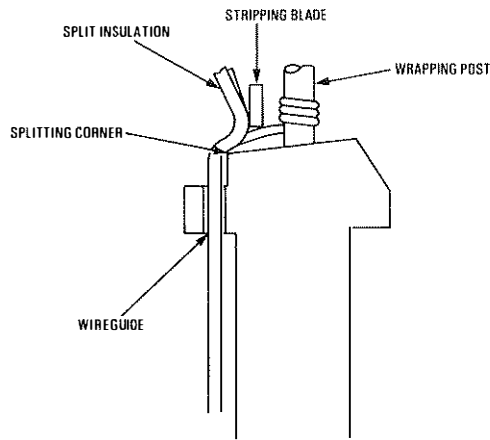


FIG. 6—Diagram showing configuration of insulation stripping strip

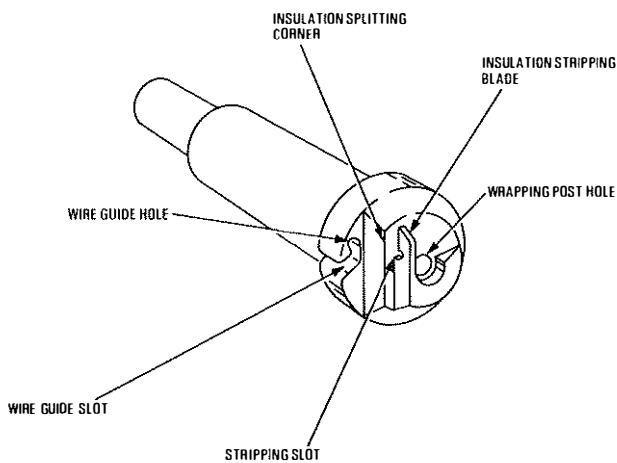


FIG. 7—Type 5 design head

design features that could help the strip. As a result of this study, a tool (see Fig. 6) was designed and manufactured which included the prime features to operate this new principle.

The reliability of the tool was tested by performing numerous terminations under simulated exchange conditions. A high success rate was achieved with no wire breakage. The only adverse effect was the occasional overwrapping of the conductor. This type of fault occurs where the approaching conductor overrides the previous turn and consequently does not make contact with the terminal pin. This fault can occur on copper wrap systems where the gun has been forced onto the pin by the operator, thereby preventing the head from retracting as the wrapping helix is generated. It was evident that the soft aluminium would be particularly susceptible to this fault and that future tool designs must endeavour to minimize this effect.

With the success of this first tool, detailed examination of the tool operation was made, resulting in further improvements. This development programme culminated in the design of the Type 5 head (see Fig. 7). Small-batch manufacture of this design commenced which, although highlighting certain manufacturing problems, enabled extended testing of the new head to be undertaken.

EVALUATION OF COMPLETED TERMINALS

As well as monitoring the mechanical performance of the tool, the electrical performance of the joint was monitored at all stages of the tool development, and an extensive collection of

results has been accumulated for the 3 principal aspects of the testing: thermal ageing; industrial atmosphere; and mechanical robustness.

The test schedule for the aluminium wire-wrap included the above categories in the following manner:

(a) *Thermal cycling* 300 cycles, followed by a heat soak at 60°C for 100 days. (Temperature cycle: -25°C to +75°C, rate-of-change 3 degrees/minute (max) with 15 minute dwell at -25°C and +75°C).

(b) *Heat soak* 140°C for 100 hours, followed by industrial atmosphere testing as BS 2011 Part 2·1 kc.1977.

(c) *Vibration testing* Vibration on a special test jig at the following frequencies: 15, 50, 100, 200, 300 Hz (each for 2 hours, 2 g (peak) at 15 Hz, 5 g (peak) on all other frequencies).

(d) *Pull-off test* Tested to BT specification D 2556A (existing copper wire-wrap specification). This measures the force required to strip the wrap off the terminal pin.

The aluminium test programme differs from the existing copper wire-wrap specification. This variation from the existing test schedule consists of the introduction of the thermal cycling, reduction in the thermal-soak temperature (compensated by increased exposure time), and an extension of the vibration testing. The addition of the thermal-cycling test has been made for the following reasons:

(a) To test for the differential expansion between the aluminium wire and the conventional copper-based alloys generally used for the terminals.

(b) To test for the differential expansion between the plastic and metallic components (applicable if insulation has been trapped within the wire wrap).

(c) To enable comparison with other aluminium contact systems evaluated by BTRD for which field experience is now available.

The modification to the thermal-soak test has been made to avoid excessive softening of any plastics that might be included in the contact system. Reduction in temperature has been compensated by increased exposure time. The requirement for a high-temperature endurance is satisfied in test (b). An extension of the vibration testing has been made to provide a more comprehensive test, and to bring the test into line with more up-to-date methods.

The electrical performance of the termination is also dependent on the detail of the terminal pin. Variation of pin coatings and the condition of the contact corners plays a major part in the initial resistance and resistance stability of the connexion. Therefore, the electrical testing included an evaluation of these aspects.

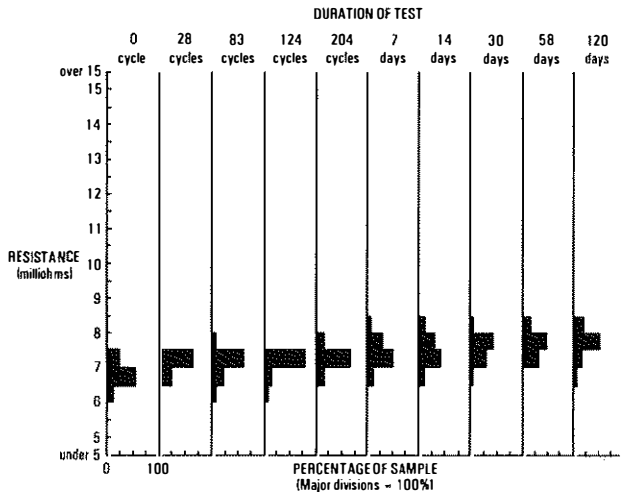
Results

The results included with this article are resistance measurements obtained for wire-wrap terminations. These measurements were taken at various intervals throughout the test sequences. The results are presented in the form of histograms. The vertical scales are calibrated in milliohms, the range varying slightly for the various batches of results. Each histogram is produced from results taken at one measurement interval. The point of measurement within the complete test is indicated at the top of each column.

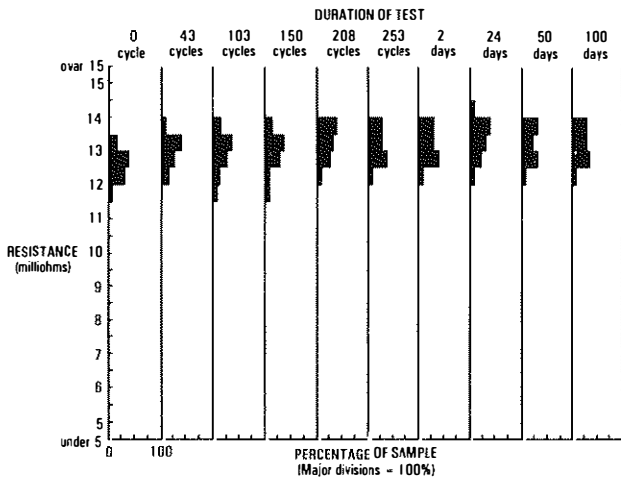
Each histogram of results presented in this article is based on a batch of 40 terminations; for convenience of measurement the values given are based on 2 terminations in series. It should be noted that during the project these tests have been repeated numerous times to increase the overall batch size tested. Analysis of the results identifies 2 aspects of terminal performance:

- (a) initial resistance; and
- (b) long-term resistance stability; that is, increase or decrease in resistance over the simulated life.

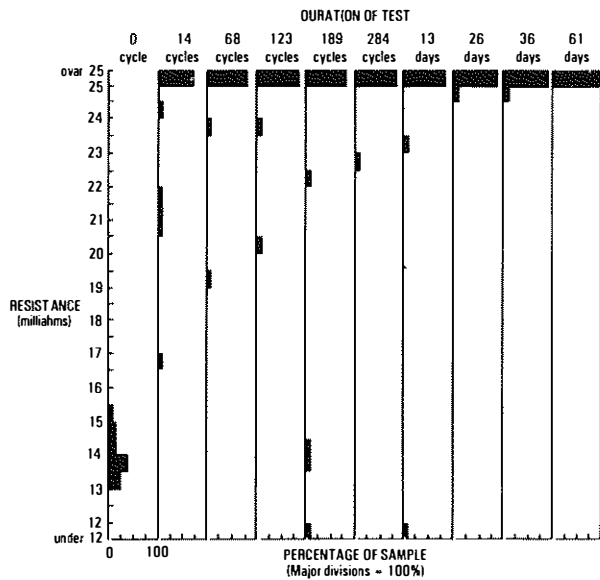
In the existing copper system, these parameters are specified



(a) Copper wire using standard cut-wrap system on nickel silver pins



(b) Aluminium wire using BTRD cut-strip-and-wrap system on nickel silver pins

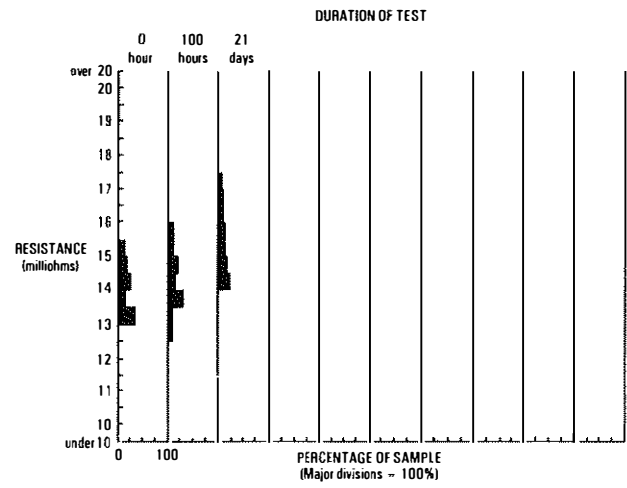


(c) Aluminium wire using BTRD cut-strip-and-wrap system on tin-plated pins

FIG. 8—Resistance change of sample during temperature cycling and thermal ageing tests

as follows: maximum initial resistance = 5 mΩ; maximum increase = 5 mΩ.

Examination of Figs. 8 and 9 shows that the aluminium wire-wrap terminal, although having a higher initial resistance than copper, provides comparable long-term stability; the



Aluminium wire using BTRD cut-strip-and-wrap system on nickel silver pins

FIG. 9—Resistance change of sample during thermal ageing test and industrial atmosphere

higher initial resistance is introduced by the increased resistivity of the aluminium conductor.

The aluminium termination maintains its performance throughout all the tests, provided the wire wrap has been made on non tin-plated pins. For the purpose of these experiments the terminations were made directly on the nickel silver base material.

The pull-off test is used as a means of on-site quality control to ensure that the correct tool is used. It does, however, provide information as to the integrity of the wrap by measuring the tightness of the wire on the pin. For this reason, preliminary pull-off measurements were made to establish how the aluminium termination compared with the copper equivalent. The values obtained for the pull-off force all exceeded the minimum value of 31 N specified for a copper wrap.

EVALUATION OF WIRE-WRAP PIN-SECTION SHAPES

The evaluation of termination performance was extended to assess the effects of variation in the shape of the pin cross-section. Particular interest was taken in the effects of different corner detail; for example, the effect of any corner burrs or corner radii. This type of detail can be introduced as a result of the original manufacturing process. Since the pins are normally formed using a press tool, the condition of the tool affects the condition of the corners. The completed pins may vary in this respect, and it was considered essential to establish the effect of this variation on the aluminium termination.

To assess the effect of the corner profile, a number of special pins were produced with particular corner detail. These batches were classified under 3 types:

- (a) *burred corners* prepared by hand grinding (oversharp);
- (b) *sharp corners* prepared by lapping (no burrs); and
- (c) *corners with radii* as per the maximum allowable on the existing copper specification.

Terminations were made using these various pins, and the performance monitored throughout the thermal-ageing tests. The results demonstrated that the burred form provided the best performance. Examination of these contacts showed that the burr locally cut into the aluminium wire, and was then deformed to provide a barb to hook the wire, and hold the contact in place (see Fig. 10). The results on the other batches of pins demonstrated that the performance deteriorated as the corner became less sharp, the worst pins being the batch with corner radii. The results from the latter batch, were not outside the performance requirement, and it was concluded that the

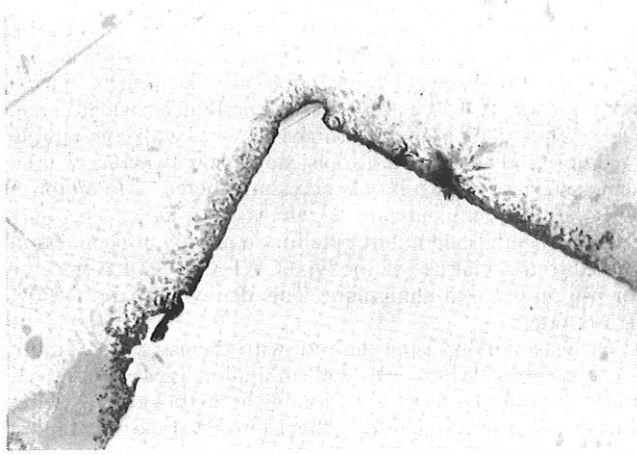


Fig. 10—Section of post contact corner with burr

existing pin specification defining the corner detail was adequate for termination of the aluminium. The specification requires a maximum corner radii of 0.08 mm, and a maximum burr of 0.05 mm.

FIELD EVALUATION

Throughout the development of the aluminium wire-wrap head, laboratory trials were carried out to establish the frequency of tool failure. These trials have demonstrated that, because of the critical nature of the process, 100% success would not be achievable. For this reason it was considered essential to establish the expected tool life, and the reliability over this life cycle. Where an observed fault has occurred, retermination can be achieved by connecting an extra length of wire using an in-line crimp connector. The saving by using the aluminium (estimated at £1M per annum) can therefore be balanced against the reliability of the tool operation, and the cost of repairing failures.

To extend the knowledge of tool operation under field conditions, a preliminary field evaluation was set up. This field work was carried out in the Portsmouth Area where a cabinet relief scheme was to be installed using a 400-pair aluminium cable. The MDF termination of this new cable was to be carried out under normal exchange conditions. The terminal block to be used was the existing JT37/1B units for which the new wrapping system had been developed. For the purpose of this installation, a special batch of blocks was manufactured with the wire-wrap pin left unplated; this amendment was made as a result of the previous termination performance studies which had demonstrated that inferior contact resulted from using tin-plated pins. The special blocks were left with clean nickel silver pins. For this installation the Type 5 head was used, this being the most advanced design tool available at that time.

Portsmouth Area supplied 2 jointers to carry out the work, both of whom had had no experience on the wire-wrapping technique. It was necessary to spend half-a-day training the operators, after which both jointers completed 100 terminations on a test rig without any failures. The termination work on the aluminium cable was completed in 2 days, with a total number of 16 failures out of the 800 terminations (2%). It was concluded that 6 of these faults were typical problems of any wire-wrap system. The remaining 10 faults were attributed to the new wrapping tool and represented a 1.25% failure rate. Where failure occurred, retermination was achieved by wire wrapping an extra length of aluminium wire which was connected with an in-line crimp connector.

The conclusions drawn from this field experiment were that

tool reliability would have to be improved, but that the exercise had proved successful as a preliminary application of the new technique.

RE-DESIGN OF SPLITTING HEAD

Problems had arisen in the small-scale manufacture of the Type 5 design of tool, and these difficulties required solutions before large-scale manufacture could be considered. This re-design also provided the opportunity to incorporate further modifications to overcome the problems encountered during the preliminary field evaluation.

Preliminary discussion with a manufacturer confirmed that the greatest manufacturing difficulties centred on the production of the stripping blade and wire-guide forms. The performance of both these features had been shown to be critical to the successful operation of the tool. The end detail of the head was complex and needed to be replaced with a much simplified form. The effect of these modifications on tool operation needed to be assessed. To achieve this, a series of heads incorporating a series of design alterations were manufactured.

The 2 main modifications resulted in a change in the wire guide, and the re-design of the end face detail of the tool. The wire guide can now be produced by a combined drilling and slitting operation. The complex end detail which consisted of various ramps and counterbores was replaced with a single compound angled face which could be easily produced by profile grinding. Unfortunately, little improvement was effected to the stripping blade because of operational restraints. Further changes were made to the wire clearances within both guide and stripping blade. These alterations were made to minimize the problems of incomplete wire threading. The new production version of the tool was designated *Type 8* (see Fig. 11), and a small quantity of heads were produced to this new design for evaluation.

LONG-TERM RELIABILITY OF THE WRAPPING HEAD

A trial was set up to study the effect on reliability of tool wear and variations in operator performance, and conductor and insulation manufacturing tolerances. BT's Procurement Executive Factories Division agreed to undertake the investigation, with the work to be carried out at Bovay Place factory.

For the trial, a test rig was produced to simulate the exchange terminating situation. Heads of the Type 8 design were made available and a suitable aluminium cable supplied. Four factory technicians were given preliminary training in the use of the tool, and the trial commenced in April 1980.

The first tool completed a total of 50 000 terminations, but the fault rate was higher than originally hoped, the failure rate

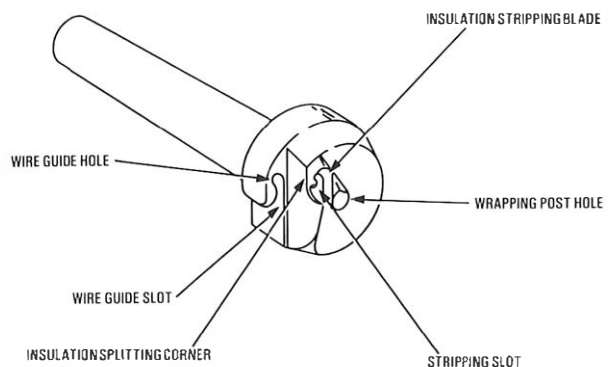


FIG. 11—Early Type 8 design head

increasing toward the end of this 50 000 (overall failure rate 1.88%). Examination showed that the tool was worn out. Detailed examination of the failures showed them to be caused by a failure of the strip process. Since this failure rate was not acceptable to the Transmission Department, further tool modifications were considered.

Modifications were incorporated into another head, which was then evaluated at Bovay Place. Results showed that stripping performance had been improved significantly. The head completed 100 000 operations with a relatively low failure rate (overall failure rate 0.17%).

A further head of the Type 8 design was subjected to further testing at Bovay Place to confirm the previous result. This particular tool was totally produced by a manufacturer using specially designed jigs and tools. Although this tool was run for a total of only 50 000 operations, this was sufficient to confirm a comparable performance with the previous head (overall failure rate 0.18%).

CONCLUSIONS

The study described in this article confirms the complex nature of aluminium termination. Furthermore, termination of aluminium by wire wrapping has necessitated considerable extension of the existing techniques, particularly where the aluminium conductor is used with foamed polyethylene insulation as is the case within BT. It is apparent that the economic advantages of using aluminium cannot be fully realized unless the terminating problems can be overcome. Any effective aluminium termination will have to be more sophisticated if it is to provide comparable performance with copper. Consequently the aluminium wire-wrap tool that has been developed is more complex than its copper equivalent.

The aluminium wire-wrap system that has been described has been evaluated on 2 aspects:

- (a) electrical performance of the completed terminal; and
- (b) reliability and repeatability of terminating-tool operation.

On both of these aspects, the results identify important points which must be considered for any future use of the system. In the case of (a), good results have been achieved throughout the various tests, provided the terminal pin is not tin plated. The clean nickel silver pins have been shown to give good results. Good termination performance is also dependent on a good post profile, with a preference for sharp or burred corners. Poor contact results if excessive corner radii exist on the pins. The conclusion on this aspect of post profile is that BT's current copper wire-wrap specification (D 2556A) defines adequate detail.

The consideration of tool reliability unfortunately is not so clear. A totally reliable tool would seem impractical if not

impossible. The inevitable increased complexity of the tool function has made it more sensitive to the properties and size of conductor and insulation. The results obtained during the tool-evaluation exercise do give a good indication of typical performance. It would seem reasonable that, provided large-scale manufacture of the tool can be achieved with comparable precision to that of the test tools, similar performance will be achieved in the field. It is only necessary, therefore, to establish whether the identified failure rate is acceptable. The only previously published failure rate for an aluminium connexion related to the trial use of the type CWI 1A crimp connector for use on 0.6 mm aluminium. This demonstrated a 0.17% failure rate⁵.

The feasibility of using the tool with the associated failure rate presents little practical problem. Failure is easily observed and can be simply rectified by joining an extra length of wire, thus enabling re-termination. This is provided that the failure rate does not make it impractical to accommodate the crimp connectors within the wiring loom. Unfortunately, insufficient information is available to provide a complete cost analysis. It is estimated, however, that the potential savings of direct termination of the aluminium to the MDF would be approximately £1M per annum. The cost of joining an extra length of wire when termination has failed is estimated at £1 per pair of conductors.

In conclusion, the new aluminium wire-wrap system could still be introduced and demonstrate a considerable cost benefit. It is unlikely that operation of the new technique will be perfectly reliable, but provided the wire breakages and strip failures are rectified and the termination is made with the suggested pin conditions, good life performance can be expected.

ACKNOWLEDGEMENTS

The author wishes to thank his colleagues in BTRD for their assistance with this project.

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8·448 Mbit/s Digital Line Systems on Carrier Cables

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UDC 621.394.4

From 1937 onwards, carrier cables were installed in the UK and formed the backbone of the main network until they were superseded by coaxial cables. Much of the repeater station equipment associated with carrier cables, which is to a large extent still valve operated, is becoming increasingly difficult to maintain, although the cables are expected to be serviceable for many years hence. British Telecom therefore intends to re-equip some of the cables to permit digital transmission at 8·448 Mbit/s. This article describes the design considerations, equipment and field trial of 8·448 Mbit/s systems on carrier cables.

INTRODUCTION

The carrier cable network comprises a route length of 8000 km, which interconnects all major towns in the UK. Two-cable working is used throughout, with one cable for each direction of transmission. Each cable has 24 pairs of 1·27 mm conductors, and each pair can carry 24 unidirectional speech channels, frequency multiplexed in the band 12–108 kHz to give a maximum capacity of 576 channels. Although some of the cables have been in the ground over 40 years, their condition is still generally satisfactory, but the associated equipment in repeater stations is becoming increasingly difficult to maintain. In 1972, some preliminary measurements indicated that the cables could be used for the transmission of an 8·448 Mbit/s digital signal on 20 of the 24 pairs, again using separate cables for each direction of transmission. This would give a maximum capacity of 2400 channels, with the remaining pairs used for supervisory and engineering speaker purposes.

The following terms of reference were therefore adopted for the design of an 8·448 Mbit/s digital line system working on carrier cables:

- (a) 2-cable working to be used effectively to eliminate near-end crosstalk;
- (b) up to 20 pairs in each cable to be used for digital transmission;
- (c) line power feeding to be provided from existing repeater stations;
- (d) continuous in-service monitoring of each digital line section (DLS) to be provided at the terminal stations;
- (e) in-service fault location to be provided, using a supervisory system common to all 20 DLSs; and
- (f) error ratio to be less than 1×10^{-10} per kilometre.

In February 1977, the equipment development contract, including supply and installation of a field-trial system, was let to Plessey Telecommunications Ltd. (PTL).

At an early stage in the development, it was decided to adopt a ternary line code, which would translate successive groups of 4 binary digits into 3 ternary symbols, thereby reducing the line symbol rate to 6·336 Mbaud. This has the advantage of lowering the centre frequency of the energy sent to line and, hence, maximizing the distance before regeneration of the pulses is required.

CABLE PERFORMANCE

Before the equipment design could be considered in detail, comprehensive information on the transmission performance of the cable network was required. The cables are of paper-core quad (PCQ) construction, with 1·27 mm copper conductors, encased in a lead sheath. As with any symmetrical pair type of cable, an important objective during manufacture is to minimize crosstalk between pairs. With quad type of construction, crosstalk between the 2 pairs within a quad

predominates over that between pairs from different quads. During installation, the joints between cable lengths were tested and selected to effect a reduction in the overall far-end crosstalk between pairs.

The manufacturing and installation specifications of the cable featured electrical testing at frequencies below 120 kHz, but the performance of the cable at higher frequencies was not known, nor was the difference in performance between the various makes of cable and over the period of manufacture. To that end, British Telecom embarked on a programme of measurements on a representative sample of 12 installed cables, covering 4 manufacturers and 3 periods of manufacture: pre-1940, 1940–50 and post-1950. The measurements were performed on 3 km sections, the nominal anticipated regenerator spacing, and included:

(a) Far-End Signal-to-Crosstalk Ratio

The crosstalk performance of all pair combinations was measured at 3·168 MHz (the frequency of the half symbol rate), with some pairs selected for additional measurements over the frequency range 10 kHz to 6 MHz.

(b) Insertion Loss

The insertion loss of all pairs was measured at 3·168 MHz, with some pairs selected for more detailed examination over the frequency range 10 kHz to 6 MHz.

(c) Characteristic Impedance

Swept-frequency impedance measurements were conducted on all pairs. Open- and closed-circuit impedance measurements permitted the primary and secondary line coefficients to be computed.

In addition to the measurements on installed cables, 2 drum lengths of cable (approximately 650 m) were temperature cycled over the range -10°C to $+40^{\circ}\text{C}$ at the British Telecom Research Laboratories to ascertain the temperature coefficients of insertion loss, phase delay, resistance and capacitance, and the effects of temperature on crosstalk.

From the cable test results, a trinomial expression was derived for insertion loss at 10°C for a nominal cable, as follows:

$$\begin{aligned} \text{Insertion loss (in dB/km)} &= 0\cdot02 + 6\cdot16 \sqrt{f} + 2\cdot329f, \\ &= 18\cdot36 \text{ dB at } 3\cdot168 \text{ MHz} \\ &\quad (55\cdot1 \text{ dB for a 3 km section}), \end{aligned}$$

where f is the frequency in megahertz. This formula, however, does not show the spread of insertion loss between different cables, which was found to be almost 5 dB for a 3 km section. From the temperature tests, it was shown that an increase in cable temperature from 0°C to 20°C increased the insertion loss of a 3 km section by about 4 dB.

The far-end signal-to-crosstalk ratio measurements revealed that crosstalk at the higher frequencies would be a limiting factor. A fundamental feature of digital transmission is that a small change in signal-to-noise ratio at the decision point of a regenerator produces an order of magnitude change in the error ratio. This is illustrated in Fig. 1 for a regenerator with

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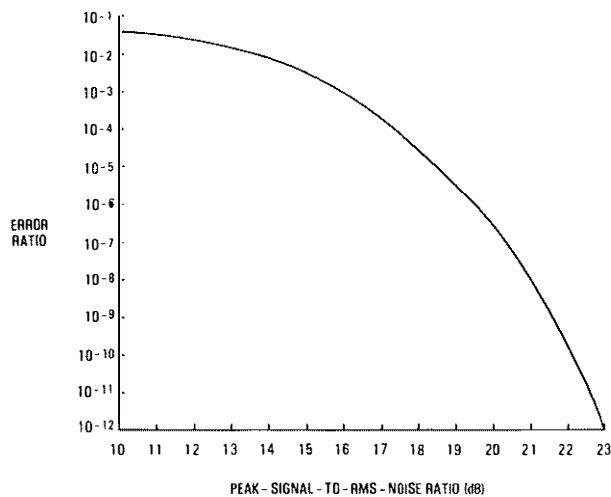


FIG. 1—Error ratio for given signal-to-noise ratios at the decision point of a regenerator with ideal equalization

TABLE 1
Parameters for a 3.3 km Section of Carrier Cable

Nominal impedance at 3.168 MHz	130 Ω
Minimum insertion loss at 0°C at 3.168 MHz	55.5 dB
Maximum insertion loss at 20°C at 3.168 MHz	66 dB
Far-end signal-to-crosstalk ratio for 19 sine-wave disturbers at 3.168 MHz	26 dB minimum

ideal equalization, assuming Gaussian amplitude distribution for crosstalk noise; thus, a crosstalk limit must be specified such that adequate system margins are maintained. This limit has been expressed in terms of the sine-wave crosstalk ratio at 3.168 MHz, because good correlation exists between this parameter and the digital peak signal-to-RMS crosstalk ratio at the decision point. A figure of 25.2 dB was established as the design limit for 19 sine-wave disturbers because, when used with a correlation factor of 6.6 dB, this yields a digital signal-to-crosstalk noise ratio of 31.8 dB. This enables error ratios of 1×10^{-10} per kilometre to be achieved with a 10 dB margin for imperfect equalization, thermal noise and regenerator ageing.

It was concluded that the digital equipment could be designed to accommodate regenerator section lengths of up to 3.3 km, and the cable parameters for a 3.3 km section are summarized in Table 1.

DESIGN CONSIDERATIONS

Interface Conditions

To ensure compatibility between items of 8.448 Mbit/s transmission equipment that are interconnected within a station, such as multiplexes and line systems, it is essential that certain interface conditions are defined. The digital signal presented at the 75 Ω coaxial output port of the equipment complies with CCITT† Recommendation G703: the binary digit rate is 8.448 Mbit/s ± 30 parts per million; the signal is HDB3 encoded; and pulse shapes are nominally rectangular, with a peak voltage of 2.37 V and a 50% duty cycle. The signal presented at an input port will have a different pulse shape because of the effect of the coaxial cable interconnecting with the preceding transmission equipment; the length of such cabling is limited to ensure that the loss at 4.224 MHz does not exceed 6 dB.

† CCITT—International Telegraph and Telephone Consultative Committee

Line Code

Before transmission over the cable, the binary information at 8.448 Mbit/s must be encoded to meet the following criteria.

(a) The energy spectrum of the line code must have minimal low-frequency components and no zero-frequency component. This has 2 benefits: first, it enables the digital equipment to be transformer coupled to the cable pairs, which facilitates rejection of common-mode signals; second, power from a constant-current source can be fed over the phantoms of the digital transmission pairs to supply dependent regenerators (that is, regenerators remote from repeater stations).

(b) The line code must contain adequate timing information because the regenerative process requires the transmitted signal to be re-timed, this timing information being derived from the received line signal.

(c) The structure of the line code must be such that any errors in the line code can be monitored.

These 3 criteria could be met by transmitting the interface signal (8.448 Mbit/s encoded into HDB3), via suitable impedance-matching components, directly into the cable pair. However, because cable attenuation increases with frequency and far-end crosstalk worsens with frequency, it is important to limit the bandwidth as far as possible to maximize the regenerator spacing.

The 8.448 Mbit/s HDB3 coded interface signal is therefore converted into a ternary code, MS43, which has three-quarters of the bandwidth of the HDB3 signal, before transmission over the cable. The HDB3 signal is first decoded to the binary level and then each successive block (or word) of 4 binary digits is converted into a 3-element ternary word, according to the particular version of MS43 code, at a symbol rate of 6.336 Mbaud.

To minimize low-frequency components and to enable errors to be monitored, the code is structured such that the digital sum variation (DSV) is restricted. The DSV is the difference in the running count of positive and negative symbols, sometimes referred to as *cumulative disparity*. Table 2 shows the MS43 translations for the 16 possible combinations of 4-bit words. It can be seen that, for any 4-bit word, there are 3 possible translations of 3-element ternary words. The particular translation chosen depends on the cumulative disparity at the end of the previous ternary word, and is such as to prevent the occurrence of illegal values of cumulative disparity.

This version of MS43 code was selected for its relative ease of implementation. It can be seen that the first 8 words of the R2 translation are the same as the first 8 words of the R3 translation and that the last 8 words of the R2 and R3 translations are the inverse of the respective first 8 words. All the encoding information can be held in a 32 × 8 bit memory.

Error Monitoring

At the end of each ternary word, the cumulative disparity will have one of 4 values although, within words, the cumulative disparity can have one of 6 values. These are all permissible values, but if a forbidden value is reached (that is, higher or lower by one than the permissible limit), an error must have preceded it. Fig. 2 shows how a ternary error causes the disparity limit to be exceeded on the next occasion that a cumulative disparity peak of the right sign occurs. Error detection is therefore based on shift registers (of an up/down form), located at every point that the DLS line signal is to be monitored.

To ensure errors are detected, the upper and lower limits of cumulative disparity values must be attained more frequently than errors occur. With the particular version of MS43 code chosen, and with a random binary input, the mean number of ternary symbols between successive occurrences of the cumulative disparity limits is 67; this allows error ratios of 1×10^{-3} to be monitored with confidence.

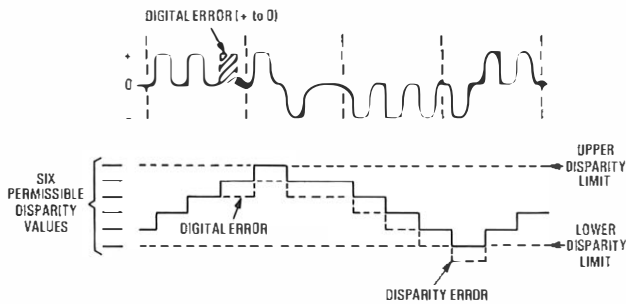


FIG. 2—Error monitoring principle

TABLE 2
MS43 Translation Table

Binary Code	MS43 Translation								
	R1			R2			R3		
0000	0	+	+	-	0	0	-	0	0
0001	+	+	+	-	+	-	-	+	-
0010	+	0	+	0	-	0	0	-	0
0011	+	+	0	0	0	-	0	0	-
0100	-	+	+	-	-	+	-	-	+
0101	+	-	0	+	-	0	+	-	0
0110	+	0	-	+	0	-	+	0	-
0111	0	+	-	0	+	-	0	+	-
1000	0	-	+	0	-	+	0	-	+
1001	-	0	+	-	0	+	-	0	+
1010	-	+	0	-	+	0	-	+	0
1011	+	+	-	+	+	-	+	-	-
1100	0	0	+	0	0	+	-	-	0
1101	0	+	0	0	+	0	-	0	-
1110	+	-	+	+	-	+	-	-	-
1111	+	0	0	+	0	0	0	-	-

Translation $\begin{Bmatrix} R1 \\ R2 \\ R3 \end{Bmatrix}$ is used when the running digital count is $\begin{cases} \text{zero} \\ \text{one or two} \\ \text{three} \end{cases}$

Word Alignment

To decode the MS43 signal back to binary in the receive apparatus at the terminal station, it is essential that the alignment of the ternary word is correct; that is, the correct 3-element window is identified. From Table 2, it can be seen that this version of MS43 does not contain the all-zero ternary word, which is an illegal word. However, the combination is present within certain successive words; for example, $++0, 00-$ or $+00, 0-+$. This forms the basis of alignment; if the decoder detects more illegal words than could reasonably be ascribed to line errors, the decoder is assumed to be out of alignment and it alters its phase until correct alignment is achieved. To ensure the decoder can differentiate between illegal words arising from line errors and those due to loss of alignment, a strategy is adopted whereby the phase of the decoder is altered only if more than 8 illegal words are detected in 256 successive words.

Scrambling

A random binary input has to be maintained at all times to enable successful error-rate monitoring based on exceeding the cumulative disparity limits, and decoder word alignment based on the detection of the illegal all-zero ternary word. Certain regular patterns in the binary input will produce line signals that do not occupy the full range of legal cumulative disparity values or do not have the necessary groupings of 3 zeros for alignment. Thus, at the transmit terminal, the binary signal is scrambled before MS43 encoding and, at the receive

terminal, a self-synchronizing descrambler restores the original binary information.

Error Multiplication

As a consequence of reducing the line signal bandwidth by using a ternary code, single ternary errors occurring on the line may result in more than one binary error. For example, from Table 2, it can be seen that one line error, changing the ternary code $0++$ to $0+0$, gives a binary code of 1101 instead of 0000, an error multiplication factor of 3, spread over 4 bits. For this version of MS43, the maximum error multiplication is 4, with a mean multiplication of $2 \cdot 2$.

The descrambling process, introduces further error multiplication, giving an overall mean extension of 5, with a maximum error multiplication of 7 spread over a maximum of 19 bits. All built-in signal monitors, although counting ternary errors, display the equivalent binary error ratio by using an appropriate multiplying factor.

TERMINAL TRANSMISSION EQUIPMENT

The transmit and receive apparatus for up to 20 DLSs, including cable terminating and power-feeding equipment, the supervisory control and engineering speaker apparatus, are all housed in one type-62 equipment practice rack, 2.75 m high. Fig. 3 illustrates the terminal station rack layout, with photographs of the speaker and supervisory shelves, and a digital line terminating shelf containing the transmit, receive, and power-feed units for 2 DLSs, with the associated shelf alarm unit.

Line Transmit Unit

The transmit unit performs the code conversion of the HDB3

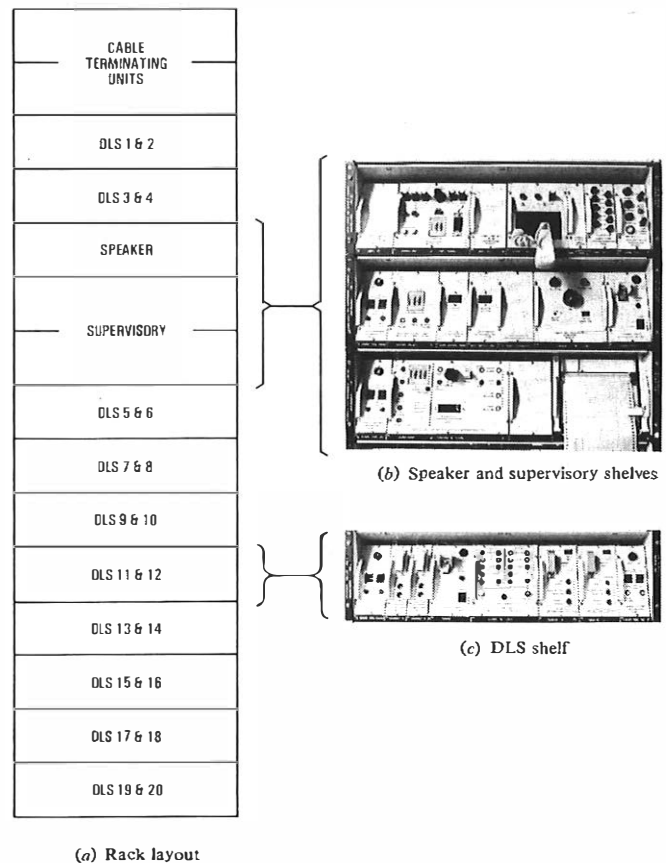
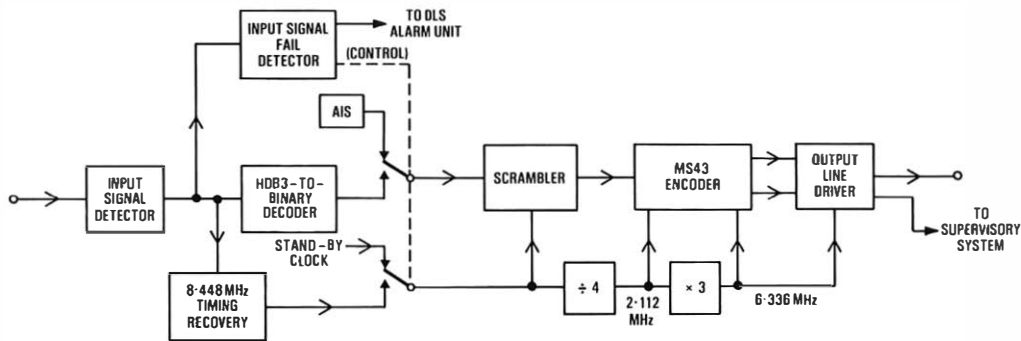


FIG. 3—Terminal station equipment



AIS—Alarm indication signal

FIG. 4—Block diagram of line transmit unit

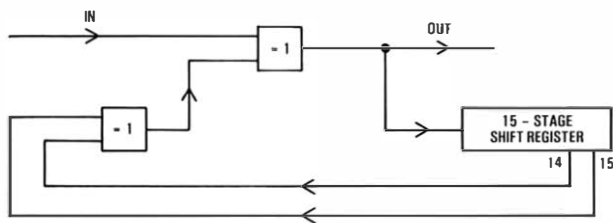


FIG. 5—Logic diagram of scrambler in transmit unit

interface signal to the MS43 ternary line code, with the necessary scrambling of the binary signal. A block diagram of the transmit unit, one of which is required for each direction of transmission of a DLS, is shown in Fig. 4.

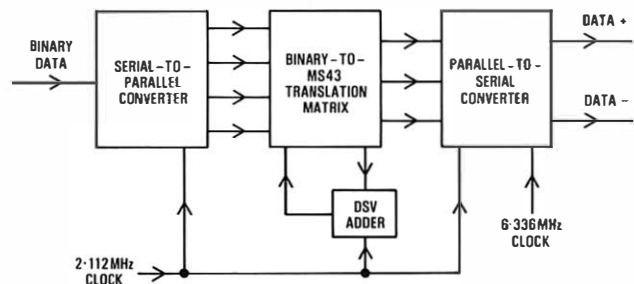
The incoming HDB3 signal, which may be attenuated by preceding coaxial cable within the station, is first detected and restored to identifiable logic levels; it is then applied both to the HDB3-to-binary decoder and to the timing recovery circuit which produces a timing waveform at the symbol rate of the input signal, 8-448 Mbit/s. The timing signal, and its sub-multiples, are required to control subsequent logic units. If the input signal fails, an alarm is extended to the shelf alarm unit, a stand-by clock is switched in, and an alarm indication signal (AIS), binary all ones, is forwarded to prevent subsequent signal monitoring apparatus from detecting signal failure.

The scrambler (see the block diagram in Fig. 5) is based on a 15-stage shift register, with the fourteenth and fifteenth stages combined with the input signal via exclusive-OR gates, thus adding a pseudo-random sequence of $2^{15} - 1$ bits to the binary input signal.

After scrambling, the binary sequence is encoded into MS43; a block diagram of the encoding process is shown in Fig. 6. Successive blocks of 4 bits are clocked through a serial-to-parallel converter, before being applied to the translation matrix held in a read-only memory. An adder keeps check of the cumulative disparity, so that the appropriate translation (R1, R2 or R3 of Table 2) is selected for the next word. The output from the translator is fed to a parallel-to-serial converter having 2 outputs, to indicate positive and negative pulses. The outputs are fed to the line driver stage to give a 75Ω unbalanced output to the cable terminating unit (CTU), and an additional output is fed to the supervisory system for monitoring purposes.

Line Receive Unit

The receive unit performs essentially the inverse function of the transmit unit, with the addition of equalization, level detection and jitter reduction. The received line signal is applied, via a CTU, to the 75Ω unbalanced input of the



DSV—Digital sum variation

FIG. 6—Block diagram of MS43 encoder in transmit unit

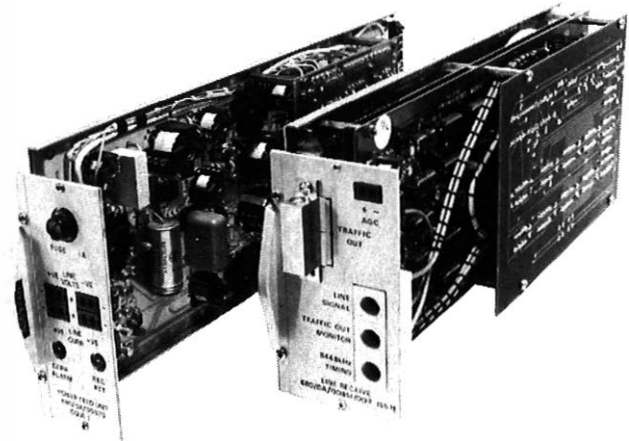


FIG. 7—Line power-feed unit and line receive unit

receive unit, a photograph of which is shown in Fig. 7, with a block diagram in Fig. 8.

The equalization and level-detection stages are almost identical to those used in the dependent regenerator (discussed later), with the 2 outputs from the level detectors indicating the presence of positive and negative ternary pulses. The 6-336 MHz timing signal is derived from an auxiliary tank circuit; this works in conjunction with the main timing recovery circuit and thereby avoids the occurrence of missing clock pulses with high received error ratios (1×10^{-3}) which might cause the receive unit to assume that alignment has been lost.

The 2 outputs from the level detectors are fed to 2 serial-to-parallel converters, which are clocked at 6-336 MHz before being applied to the MS43-to-binary translation matrix, as shown in the block diagram in Fig. 9. Thus, at each 6-336 MHz clock instant, a 4-bit word is presented to the input of the latch.

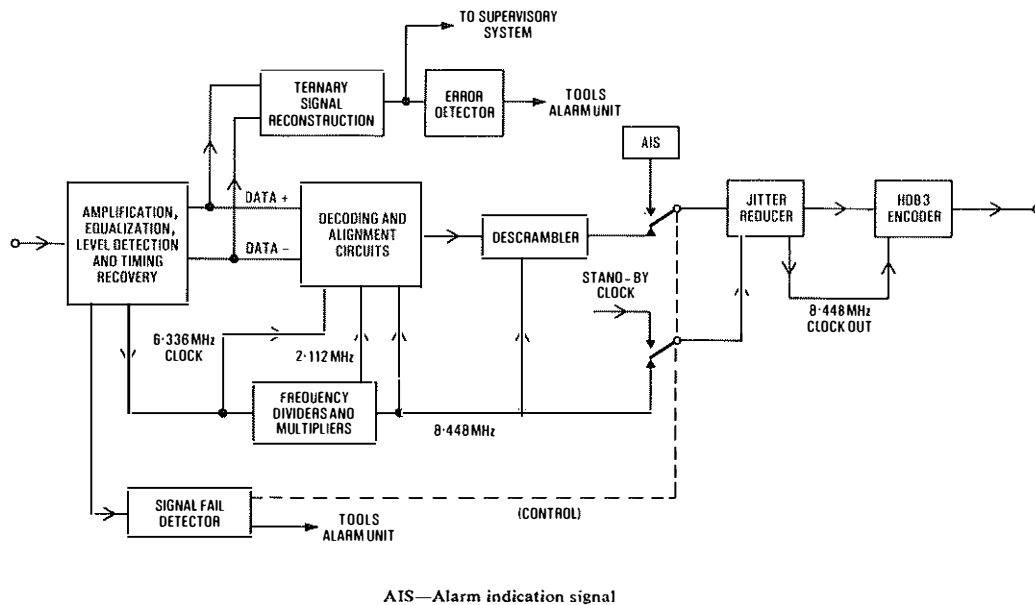


FIG. 8—Block diagram of line receive unit

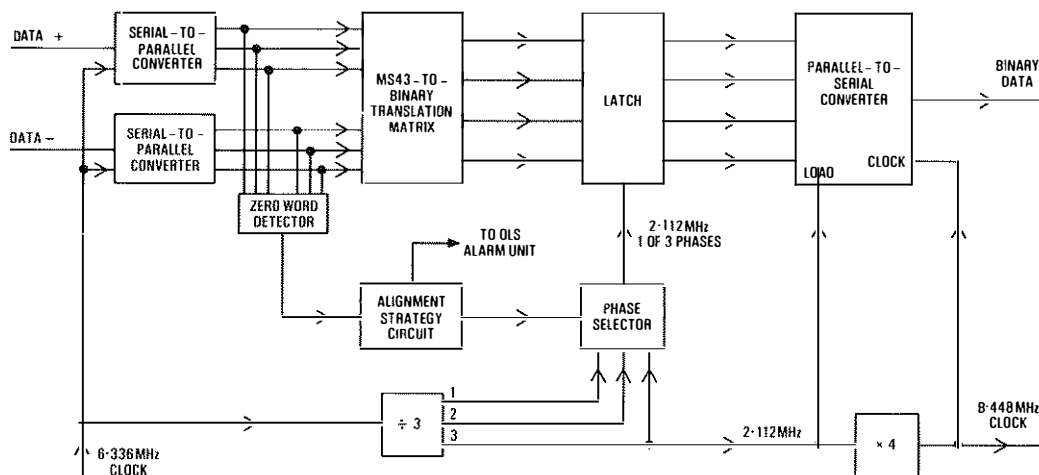


FIG. 9—Block diagram of MS43 decoder and alignment circuits

This latch is clocked with a 2.112 MHz signal, produced by a divide-by-3 circuit, the phase of which is selected so that the illegal all-zero ternary word does not occur at the clock instant. An alignment strategy circuit ensures that re-alignment is not attempted because of line errors producing the all-zero word. To ensure that changes in sampling phase at the latch during alignment do not effect the clock integrity of the binary output (that is, to re-align without slip), one of the 3 phases is permanently fed to both the times-4 frequency multiplier and the load input of the parallel-to-serial converter.

The binary data thus derived is descrambled before being applied to the input of the jitter† reducer. The jitter, which accumulates in a chain of regenerators¹, is removed by reading the binary data into a store under the control of the derived timing signal that has jitter superimposed. The data is read out from the store under the control of a signal from a phase-locked oscillator, controlled by the derived timing signal. Any short-term variations in the timing of the binary data are thus filtered out by the time constant of the oscillator control loop, but the mean input and output rates are the same. Finally, the jitter-reduced binary signal is encoded into HDB3 to conform to the 8.448 Mbit/s interface requirements.

† Jitter—short-term variations of the pulses from their ideal positions in time

Cable Terminating Equipment

Within the station, the main cable pairs are extended to the rack by using 3 m lengths of flexible screened-twin cable, which terminate (using connectors) on the CTUs. The CTUs contain the appropriate line-matching transformers (75 Ω to 130 Ω in the case of the DLS), with phantom access for line power feeding and components for surge protection.

DEPENDENT EQUIPMENT

Dependent equipment (that is, equipment located remotely from a terminal or intermediate station from which it receives its power), comprises regenerators and an associated supervisory unit. Dependent equipment locations are spaced up to 3.3 km apart, with up to 12 such locations between the power-feeding stations.

The regenerator is required to produce at its output a replica of the original transmitted pulse sequence. This is achieved by 3 functions: equalization, level detection and retiming.

Equalization

The function of the equalizer is to compensate for the attenuation/frequency distortion produced by the preceding cable section, and to shape the pulses so that they can be reliably detected and retimed.

It is neither sensible nor practicable to equalize for the highest frequencies contained in the pulse waveform. The frequency response of the path between the output of the preceding regenerator and the level detector, with realizable equalization, will therefore be that of a low-pass filter (LPF). Transmission of any rectangular pulse through an ideal LPF produces overshoots and ringing, and the ringing may interfere with adjacent pulses (inter-symbol interference). If, however, the path is equalized to the response of an ideal LPF, with a cut-off at the Nyquist frequency†, the ringing from a pulse will have zero amplitude at the time instant allocated to the centre of every adjacent pulse. If all pulses could be sampled at exactly those intervals, any sequence of pulses could be transmitted. However, an ideal LPF and such precise sampling cannot be realized in practice, and so the LPF is shaped by adding a skew-symmetrical function that preserves the zero ringing amplitude at the centre of adjacent pulses. Such a function is produced by raised-cosine roll-off shaping, which is characterized by its cut-off frequency. For this system, 100% roll-off is used; that is, the cut-off frequency is 100% greater than that of the ideal LPF (see Fig. 10).

Equalization in 8.448 Mbit/s regenerators is achieved in

† Nyquist frequency is numerically equal to half the symbol rate

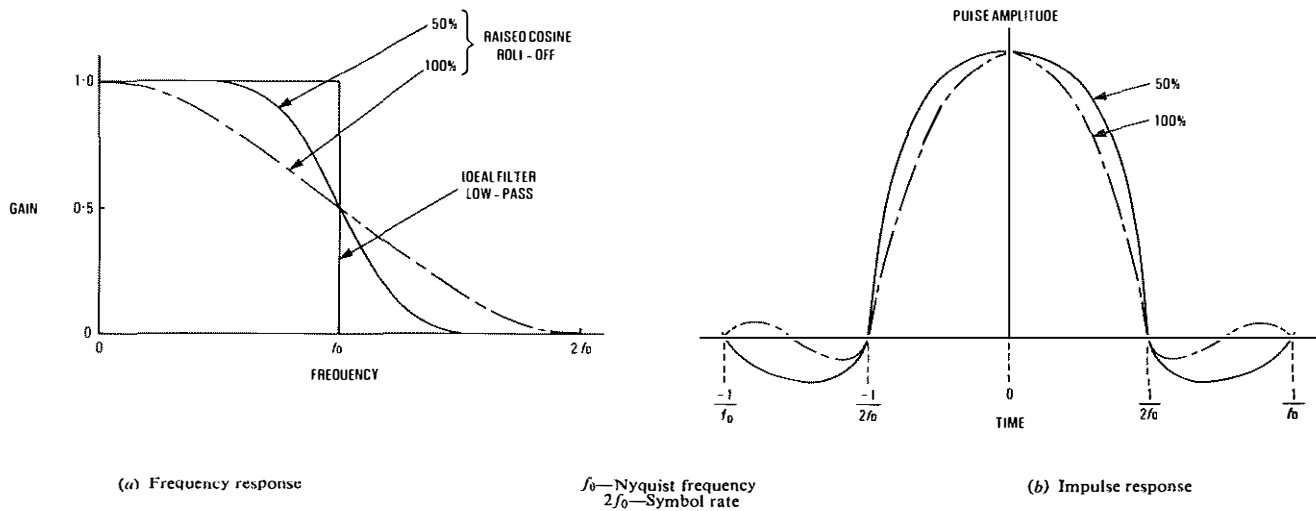


FIG. 10—Raised-cosine pulse shaping

several stages: a pre-equalizer; a 3-section main equalizer and a phase equalizer; 2 pre-set line-build-out (LBO) networks; and a bode-type automatic LBO network. A block diagram of the regenerator is shown in Fig. 11. One of the pre-equalizers is selected which, together with the main equalizer, achieves the required raised cosine roll-off impulse response for preceding section lengths of 1.2 km, 2.1 km or 3 km of cable at 10°C. To cover the complete range of cable length from 0.75 km to 3.3 km, in discrete 0.1 km steps, use is made of the pre-set LBO networks.

The automatic LBO network, which is controlled by the automatic gain control (AGC) signal from a peak signal detector, has to compensate for any remaining variations. The first variation arises from differences in cable insertion-loss characteristics, and the second from cable temperature varying over the range 0°C to 20°C. From the cable tests, it was found that the attenuation variations from both causes were substantially linear with frequency, and so the automatic LBO network has a linear characteristic with a range of ± 7 dB at 3.168 MHz. The third variation is the small error in cable length resulting from the use of 0.1 km steps in the pre-set LBO network and inaccuracies in recorded cable lengths. In this case, the linear characteristic is not quite appropriate and, in extreme cases, the pre-set flat gain adjustment within the AGC loop may be used.

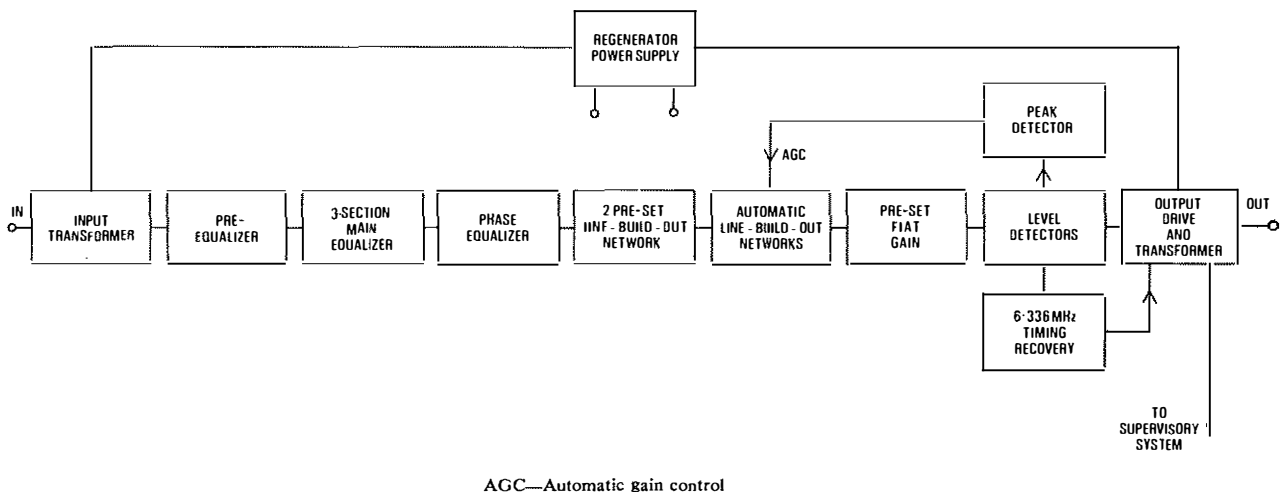


FIG. 11—Block diagram of an 8.448 Mbit/s regenerator

Level Detection and Timing Recovery

The amplifier, which follows the equalization stage, provides outputs to the following:

- (a) the AGC peak rectifier, which supplies to the automatic LBO network a direct voltage proportional to the peak amplitude of the ternary signal;
- (b) the timing recovery circuit, based on an inductance-capacitance tank circuit, which derives a 6.336 MHz signal, this being squared and differentiated to provide the precise ON and OFF timing signals needed to ensure that the pulse sequence is sampled at the optimum time; and
- (c) 2 level detectors, one provided for each polarity of the ternary signal, which indicate the receipt of a valid pulse when the amplitude exceeds a predetermined level.

When a valid pulse is detected, one of two switching transistors (the one assigned to that pulse polarity) is turned ON and then OFF under the control of the timing signal. The switching transistors thus cause regenerated pulses, of the required duration and amplitude (79 ns, 50% duty cycle, 3.3 V peak), to be transmitted to line via a transformer. An auxiliary winding on the transformer provides an output to the supervisory system for signal monitoring purposes.

Noise Immunity and Jitter

Crosstalk noise, superimposed on the pulses at the regenerator level detector, results in a finite probability that the detectors will produce an incorrect output. Moreover, jitter leads to fluctuations in the timing signal. Both these effects, which have been described in earlier articles,^{2,3} lead to a degradation in the error performance of the regenerator. The maximum regenerator section length (3.3 km) was selected to ensure that the combined effect of thermal noise and crosstalk noise would not produce an effective binary error ratio worse than 1×10^{-10} per kilometre. To prevent a significant reduction in noise margin caused by a phase shift of the sampling instant, the timing recovery circuit has been designed to have a Q-factor of about 50 and a frequency variation from nominal of $\pm 0.175\%$.

Housing

The dependent regenerator is mounted in a steel case, with the connectors (input, output and supervisory) on the top face. An inner chassis, which supports the 2 main printed-wiring boards, is isolated from the outer case because its potential lies between +80 V and -80 V as a result of the power-feeding system used. Fig. 12 shows a dependent regenerator with the case removed.

Dependent regenerators are housed in pressurized repeater cases, which are installed in footway boxes. Up to 20 regenerators and the associated supervisory unit can be housed in a repeater case, as illustrated in Fig. 13; 2 cases are therefore required at each location (one for each direction of transmission). The main cables are intercepted in manholes

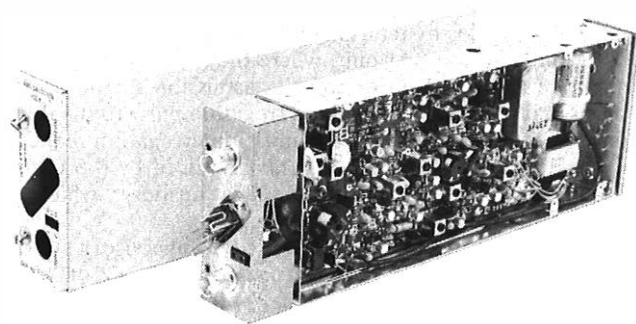


FIG. 12—Dependent regenerator with outer case removed

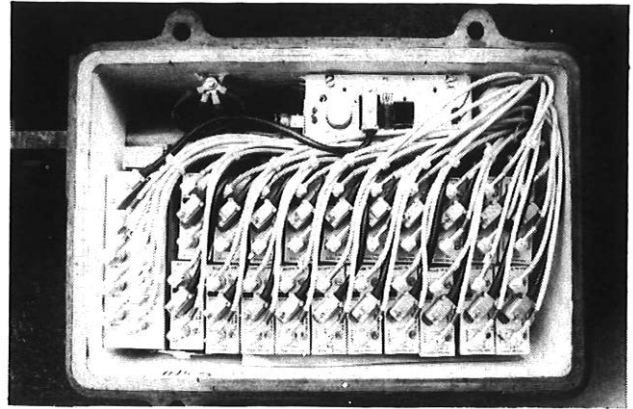


FIG. 13—Fully-equipped repeater case

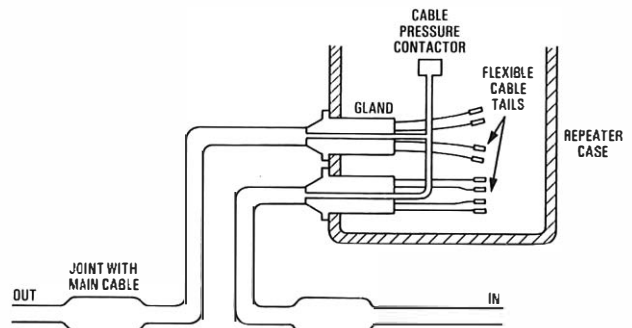


FIG. 14—Cabling arrangements for one direction of transmission at a dependent location

adjacent to the planned dependent regenerator location, and are extended to the repeater cases using tail cables, as shown in Fig. 14. Each tail cable comprises up to 10 m of 24-pair carrier cable, a bronze encased resin-filled repeater-case gland and 24 short lengths of screened-twin cable, each of which terminates in a screened connector. Considerable care had to be exercised in the design of the gland assembly to ensure that its screening was adequate to meet the crosstalk requirements between 2 such assemblies (the input and output glands to a repeater case).

Two pressure contactors are located in each repeater case, one of which is in an air-tight housing and is pneumatically connected, via an air tube in the output gland, to the main cable. The contactors interface with the supervisory unit to give warning of low pressure in the repeater case and in the cable.

INTERMEDIATE STATION EQUIPMENT

Intermediate stations are required for power-feeding purposes when the terminal stations are more than 40 km apart. All the CTUs, power-feed units, supervisory and speaker apparatus, and regenerators for up to 20 DLS are housed in one 2.75 m type-62 rack. The regenerators are electrically identical to dependent regenerators, except that they are powered from -24 V or -50 V station supplies, and their input and output impedances are 75 Ω unbalanced; line impedance matching is achieved in the CTUs.

POWER FEEDING

Power for the dependent regenerators is supplied, over the cable, from power-feed units located in terminal and inter-

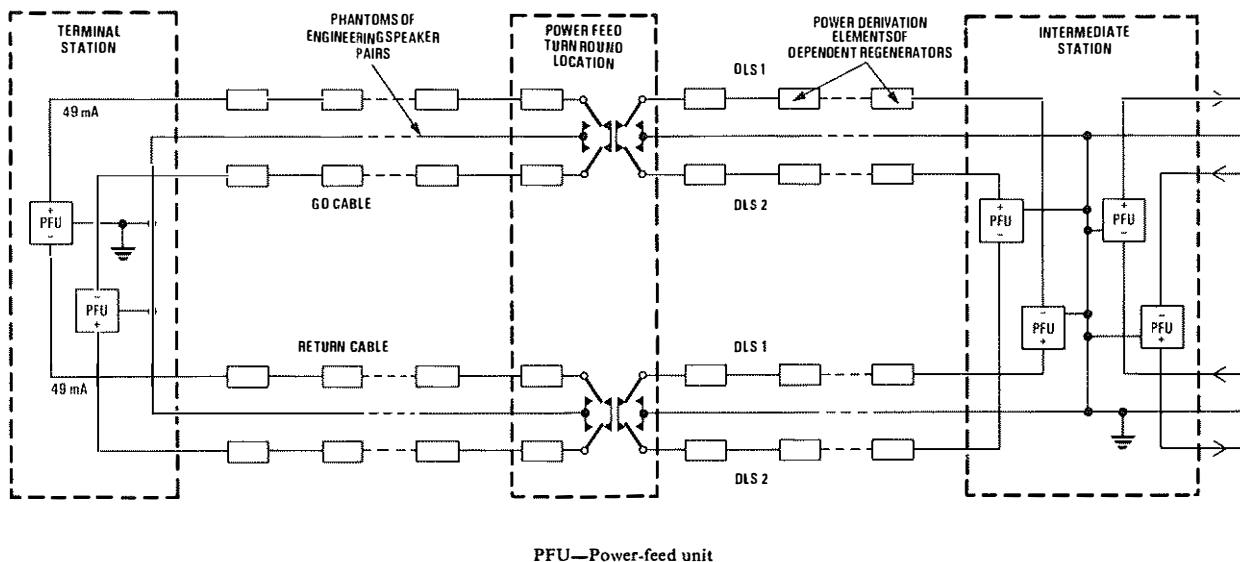


FIG. 15—Power-feed system for 2 DLSs

mediate stations. The power-feed units (shown included in Fig. 7) are connected to the phantoms of the cable pairs and, with an applied voltage of 80–0–80 V, supply a constant current of 49 ± 1 mA to up to 12 regenerators (6 on each pair of a quad). At the dependent regenerator location that is approximately midway between 2 surface stations, the power is turned round and returned to feed the regenerators on the other pair of the quad.

At each dependent regenerator, the power is derived by means of a Zener diode connected between the centre-taps on the line side of the input and output line-coupling transformers. Each regenerator has a power consumption of 500 mW.

One requirement for 8·448 Mbit/s line systems is that only one DLS should be affected by failure of one power-feed unit or the power derivation components in a dependent regenerator. This is achieved by a combination of 2 techniques (see Fig. 15).

(a) At terminal and intermediate stations, the positive and negative outputs of the power-feed units are connected to the phantoms of the pairs (one pair in each cable) carrying the GO and RETURN signals of the same DLS.

(b) In the dependent regenerators at power-feed turn-round locations, electronic voltage-sensing switches are fitted and these normally allow the current to return along the phantom of the other pair of the quad. However, if a disconnection occurs in one pair of a quad, the switch in the regenerator connected to the other pair operates to allow the current to be returned via the phantoms of the 2 engineering-speaker pairs, which are nominally at zero volts.

SYSTEM SUPERVISION AND FAULT LOCATION

Several forms of supervision are provided on 8·448 Mbit/s line systems, as follows:

(a) continuous performance monitoring of each DLS at terminal stations;

(b) continuous system monitoring to give indications at both terminal stations of loss of cable or repeater case pressure, the occurrence of a station alarm (that is, an alarm at a terminal or intermediate station), and the failure of the supervisory system;

(c) in-service location, by manual interrogation, of any DLS apparatus causing the degradation in performance as indicated in (a) above; and

(d) location, by manual interrogation, of the fault conditions highlighted in (b) above.

DLS Performance Monitoring

At terminal stations, the performance of each DLS is continuously monitored and an alarm is automatically raised if the following failure conditions occur:

- (a) loss of input traffic on the 8·448 Mbit/s HDB3 interface;
- (b) loss of received line signal;
- (c) loss of ternary word alignment; or
- (d) received error ratio above a pre-set value.

Provision is made for the connexion of a strip chart recorder to any DLS to give a permanent record of the occurrence of failures (b), (c) and (d) above, and of single line errors. All power units have low-voltage alarms and power-feed units have alarms for low and high current and high voltage conditions.

System Monitoring

Continuous system monitoring is achieved by using the 2 loop system shown in Fig. 16, which uses 2 pairs from each cable. Each loop forms a bi-directional highway to transmit information between supervisory telemetry units at each location and supervisory control apparatus (shown included in Fig. 3) at the respective terminal stations. The information is in the form of pulses of tone at 21·8 kHz, each pulse having a duration of 0·7 ms; Fig. 17 shows the sequence of pulses. An interrogation request is transmitted from the supervisory control and alarm unit (CAU) and received by the first telemetry unit on the loop, which responds by returning a marker to the CAU, followed by up to 4 alarm pulses. Coincident with the time-slot allocated to the last alarm pulse, the first unit transmits an interrogation pulse to the second unit; this responds by returning its marker and (if applicable) alarm pulses to the first unit, where they are regenerated in amplitude and width prior to re-transmission to the CAU. The second unit then sends an interrogation pulse to the third unit and so on. Thus, after each initial interrogation request, a train of marker and alarm pulses is received by the CAU, where they update the contents of a memory, which is addressable by using a location code.

If any marker pulses are not received, a supervisory *system fail* alarm is raised. If any of the alarm pulses 1, 2 or 4 are received, an indication of *loss of cable pressure*, *loss of repeater case pressure*, or the occurrence of a *station alarm* will be given by the CAU at both terminal stations.

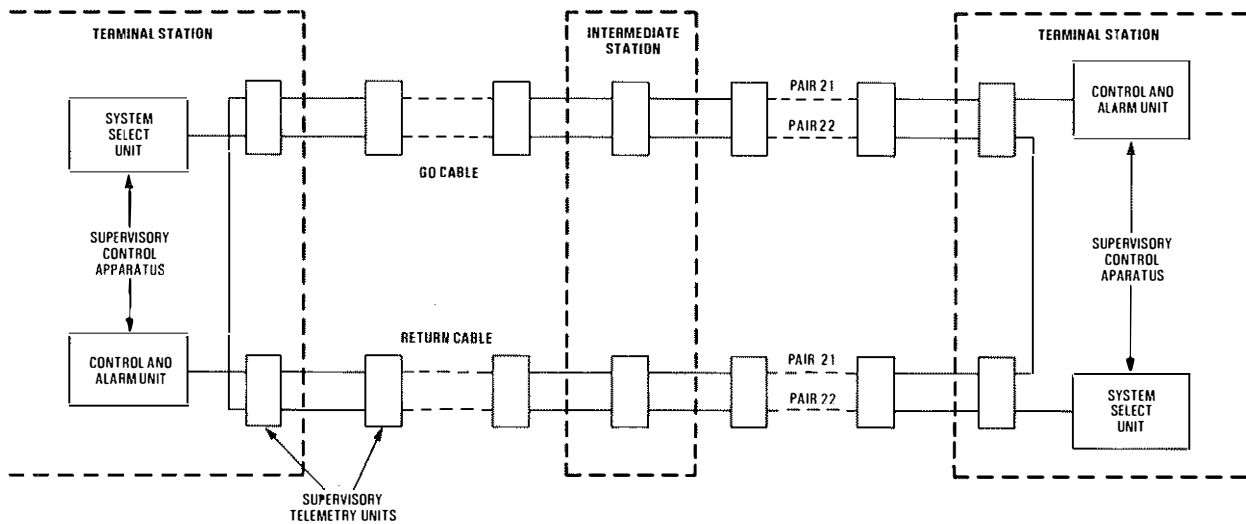


FIG. 16—Supervisory system arrangement

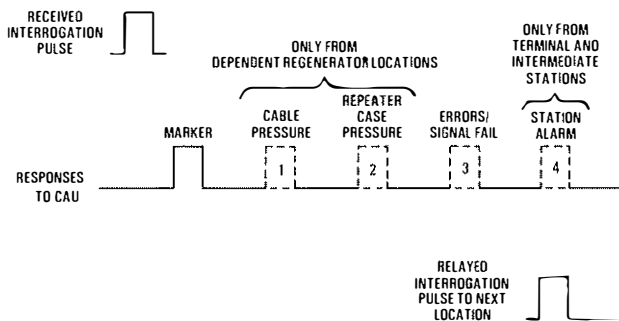


FIG. 17—Supervisory system telemetry pulse sequence

Fault Location

Locations on the route are numbered sequentially from the terminal station that is allocated as maintenance control. Thus, the control terminal station is numbered 00, the first dependent regenerator location 01 and so on. Since 2 supervisory telemetry units are provided at each location (for the GO and RETURN directions of digital transmission), the location numbers are correspondingly prefixed with 0 and 1. As the CAU memory is addressable using the location code, the faults can be located by examining the contents of the memory for each location. A manual SELECT LOCATION switch and light-emitting diode indicators on the CAU facilitate this examination.

DLS Selection and Error Monitoring

As the supervisory system is common to up to 20 DLS on the cable, a means of selecting a particular DLS for performance monitoring at any location is required. Each item of DLS transmission equipment (transmit units, regenerators and receive units) has a supervisory output bearing the ternary line code, and each supervisory telemetry unit has an associated switch module to which all the DLS supervisory outputs are connected. Under the control of a manual SYSTEM SELECT switch in the supervisory control apparatus, each switch module on the route connects the appropriate supervisory output to the error-monitoring/signal-fail detector circuits in the telemetry unit.

Errors in the ternary line code are detected, as described earlier, by using an up/down shift register to detect forbidden values of cumulative parity. The outputs from the register are stored in a counter which is cleared and reset on the arrival of every interrogation pulse. If the counter overflows before the arrival of the next interrogation pulse, an overflow indication is returned to the CAU (pulse 3 of Fig. 17). To interrogate and receive replies from the maximum number of equipment locations (64), a time interval of 3 s is necessary between interrogation pulses. A binary error ratio of 1×10^{-3} is equivalent to the occurrence, on average, of 4700 ternary errors in 3 s.

To locate faulty DLS apparatus, it is unnecessary to resolve error ratios worse than 1×10^{-5} ; that is, an average of 47 ternary errors in 3 s. It is essential, however, that the size of the counter should be such that it only overflows when there is a high probability that the error ratio has been exceeded. A counter size of 32 was chosen since, with a 3 s interrogation time, it will overflow with a 0.99 probability that the equivalent binary error ratio has exceeded 1×10^{-5} . Longer integration times of 30 s and 300 s can be manually selected on the CAU to give error ratio indication of 1×10^{-6} and 1×10^{-7} respectively.

ENGINEERING SPEAKER

The speaker apparatus is based largely on that for the Coaxial Equipment Line No. 4000A. However, because 8.448 Mbit/s line systems operate over 2 cables, the speech has to be split into 2 parallel paths. This allows any station to call and communicate with any other station or dependent location, and vice-versa; it also permits calling and communication between dependent locations.

The system uses 2 pairs, 23 and 24, in both cables to carry speech in the GO and RETURN direction, respectively (see Fig. 18). At terminal and intermediate stations, the speaker apparatus is housed in one type-62 shelf. Access to the speaker pairs at a dependent location is made using a Portable Intercommunication Set No. 5A, via a multi-way plug mounted on a plate within each repeater case.

FIELD TRIAL

The route between Salisbury and Yeovil was selected for a field trial, using cable that had been manufactured by Siemens and installed in 1938; the total distance was 64 km, and there were 21 dependent regenerator locations and an intermediate station at an existing repeater station.

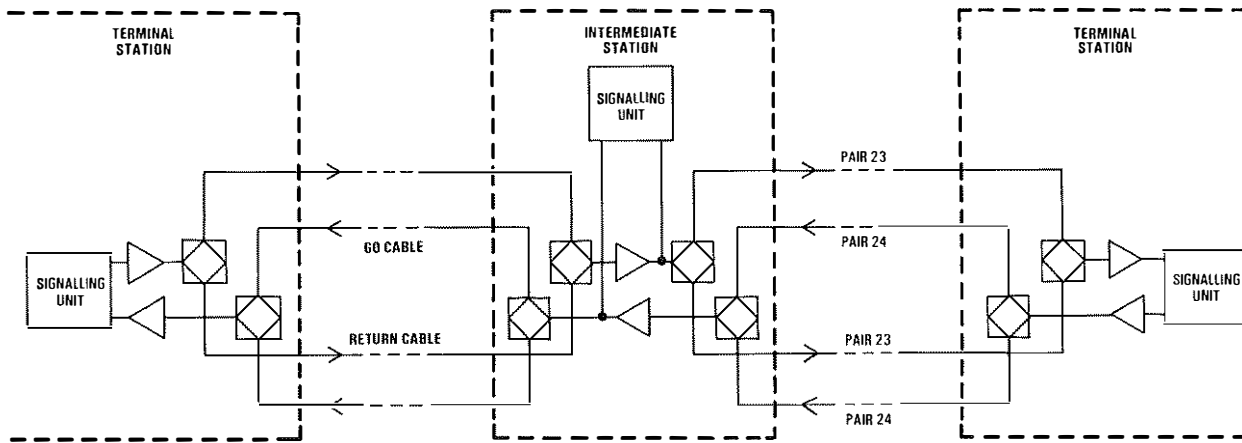


FIG. 18—Engineering speaker arrangement

Only 2 DLSs were installed on the cables because this was sufficient to prove most aspects of the system design. (The DLSs have to be equipped in pairs to conform with the power-feeding arrangements.) To confirm both the suitability of the mechanical arrangements in a fully-equipped repeater case, and the effects of crosstalk between DLSs, the first dependent regenerator location in the go direction from Salisbury was equipped with 20 regenerators. Special field-trial test apparatus, designed to generate 19 independent pseudo-random binary signals encoded into MS43, was installed at Salisbury to facilitate the crosstalk tests.

Prior to installation of the line system by PTL, British Telecom staff from the South West Telecommunications Board intercepted and extended the carrier cables to the repeater cases at the dependent locations. After the successful installation and 14 day stability run, more detailed testing of the system commenced, including jitter accumulation with 46 regenerators in tandem, and noise margins. Although the particular cable on the field trial route has an insertion-loss characteristic very close to the derived trinomial expression, the measurement results gave both the designers and British Telecom staff confidence that such systems would operate satisfactorily on any carrier cable with parameters within those summarized in Table 1. For the field trial, the design objective of a mean equivalent binary error ratio of 1×10^{-10} per kilometre was met, and the 2 DLSs ran totally error free for much of the time.

CONCLUSION

This article has described the development of an 8.448 Mbit/s DLS, designed to operate over existing 24-pair 1.27 mm conductor size PCQ carrier cable. The development culminated in a field trial that operated successfully for over 18 months. A further development is well advanced to design equipment to operate over 1.20 mm conductor size carrier cable, the principal changes being the regenerator equalizer design. The first production systems are planned to be ready for service in the first half of 1983.

ACKNOWLEDGEMENTS

The authors wish to thank their colleagues in British Telecom, in particular the staff of the South West Telecommunications Board, and those in PTL for their efforts, which led to a successful field trial. Special acknowledgement is given to M. H. J. Yates for his valued contribution throughout the development.

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The Soil as an Engineering Material

Part 2—Applications

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UDC 624.1:551

Part 1 of this article described some of the basic characteristics of the soil as an engineering material. This part presents a number of case studies showing how these characteristics affect the design and construction of telecommunications plant.

INTRODUCTION

The first part of this article¹ summarized the major features of the soil from the engineer's viewpoint. Particular attention was drawn to the great variability of the properties of rock and soil, and mention was made of the techniques used to determine these properties. This concluding part of the article illustrates by means of case studies the way in which the soil is investigated and the civil engineering work is adapted to suit site conditions. The chosen examples are of foundations for telecommunications structures in which close attention to ground conditions was especially important to ensure their safe and serviceable performance.

FOUNDATIONS FOR TROPOSPHERIC-SCATTER ANTENNAE

Several 18 m and 12 m billboard antennae (Fig. 1) have now been installed for the British Telecom transhorizon radio services for communication with offshore oil production platforms. A number of these antennae have been positioned on high ground on the southern part of the Shetland Mainland. Shetland suffers from very severe weather conditions, and these large antennae are subjected to high wind speeds, which result in very heavy forces being transmitted to the foundations.

Geology

An initial investigation of the site, prior to commencement of construction of the first antennae, had shown that there was a thick peat cover with rock beneath. The geological map of the area showed that a metamorphic rock, *phyllite*, would be found, and this proved to be the case. A metamorphic rock is

one whose original form and composition has been changed by the action of pressure and heat. Like related slates and schists, phyllite cleaves freely. This rock had once been a clay-grade sedimentary mudstone, but over 400 million years ago it had been recrystallized into its present form by the action of intense pressure in large-scale earth movements. The strong deformation of the rock had also left its mark in contorted rock structures.

Site Investigation

The initial investigation proved difficult because of the access problems posed by the several metres thick covering of peat and the cuttings created by the islanders when they had removed some of the peat for use as fuel. However, 20 boreholes were drilled into the rock with an annular cutter to enable samples in the form of cores to be taken. When crushed in a compression testing machine in the laboratory, these cores showed that the compressive strength of the unfissured rock approximated to that of a good quality concrete. The drillings also indicated that the upper 0.5–3 m of rock was affected by weathering, though the effect upon it was not fully apparent.

Foundation Construction Problems

With this data, the design of the foundations proceeded. The 18 m reflectors were supported on 10 large mass-concrete blocks keyed into the rock surface and the 12 m reflectors on 8 blocks. However, after construction had commenced and the peat cover had been removed, 2 major problems arose. It was found that the rock was more seriously weathered than anticipated and that the upper surface had the appearance of a layer of steeply-inclined slabs leaning against each other (Fig. 2). The effect was twofold: the slabs tended to break off

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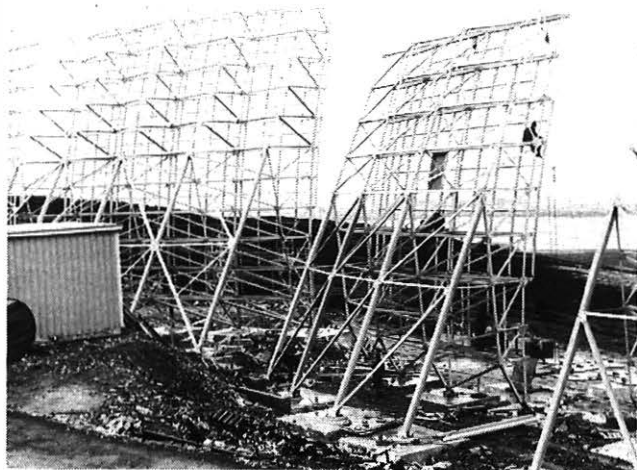


FIG. 1—Tropospheric-scatter antennae under construction on Shetland



FIG. 2—Shetland site showing fissured rock

in such a way as to cause overbreak in the excavations making them unnecessarily large; but, more seriously, the joints between the slabs were filled with soft material. This infill was a mixture of clay and peat at the top, which graded down to a mixture of small rock fragments and clay as the depth increased. This mixture, known as *clay gouge*, is a material that has been ground down to a fine particle size during earth movements or glacial action in which rock masses are ground together. The alternation of hard rock and soft gouge was serious because of the possibility of excessive and uneven settlement which could distort the antenna superstructure as the clay compressed slowly under load. Therefore, a specialist in rock mechanics was engaged to advise on a suitable excavation procedure, and the foundations were successfully constructed without further difficulty.

As more aerial systems were to be constructed nearby, the site investigation procedure for these was modified in the light of the earlier experience.

Faulting

Areas in which rocks have been subjected to intense deformation commonly exhibit what is known as *faulting*. A fault is a fracture in the rock where relative movement has taken place on either side of the fracture.

The early site investigations for the first antennae locations had not shown any significant faulting, but a fault of sufficient size to cause considerable problems if encountered on an antenna site was uncovered in a quarry that was being worked nearby (see Fig. 3). Faults can give rise to 2 particular difficulties. Firstly, the rock may still be under stress, and construction could reactivate movement and damage the foundations of a structure. Secondly, where the faults have opened up significantly and the fissure is filled with softer material, there is likely to be a rapid transition from hard rock to soft infill



FIG. 3—Shetland: clay-filled fault about 1 m wide

which may seriously affect both the design of the foundations and their construction over the fault. The necessarily limited extent of site investigation where only boreholes are used may miss such features, and so the sites of all the later antennae were cleared of peat down to the rockhead before a more detailed investigation was undertaken. This precaution proved to be well justified, as a number of faults were subsequently discovered on some of these sites. Their presence necessitated a fresh look at the design of the foundations, as the use of separate blocks under each of the columns of the antennae framework had to be ruled out because of the likely differential settlement. An economical alternative in the form of a raft foundation was adopted (Fig. 4). Instead of the usual 8 or 10 mass-concrete blocks per antenna, 2 reinforced-concrete rafts, buried and covered with excavated rock to add to the uplift resistance, were used. The main advantage of this solution was that the faults could be bridged over.

Protection of Concrete

The problem of peaty water coming into contact with the foundations necessitated protection against acidic water, and care had to be taken to ensure that all structural concrete was both rich in cement content and well-vibrated to produce a dense impermeable mass.

Summary

These antennae were constructed on virgin ground where all significant features were obscured by a thick covering of peat. Site investigation, foundation design and construction proved to be highly interactive processes, each aspect having to be rapidly responsive to changes or new findings in the others. The considerable variability of ground conditions in such locations places strains on those attempting to estimate costs prior to the commencement of work. It follows that supervision of construction work by those competent to appreciate the significance of unanticipated ground conditions is vital to ensure an economic and serviceable end result.

MADLEY 2 ANTENNA FOUNDATION

The study of antenna installation cited above illustrates the problems of construction on a rocky site. In contrast, the Madley satellite earth-station site, consisting of uncemented material to a considerable depth, necessitated quite different methods of site investigation, foundation design and construction. The overall requirement of providing a very stable base for a highly-directional antenna again applied.

At an early stage during the acquisition of the new earth-station site at Madley, a preliminary site investigation was undertaken and a single borehole sunk near to each of the 6 proposed antennae sites². The conclusions drawn indicated that this was an area with fairly uniform conditions across the whole site. However, more detailed investigations carried out subsequently showed that the conditions were much more variable and that each of the antenna systems would have to be treated as a separate problem. The history of the foundation work for the second 32 m diameter steerable antenna on the site is used here as another example of the close relationship between ground conditions and structural design.

The preliminary design of the antenna base building was based on the results of the early exploration of the site. The intention was to sit the superstructure on a massive concrete ring beam founded in the stiff gravel layer some 3 m below ground level. It was assumed that the structural loads would spread sufficiently into the gravel so that the pressures on the weaker underlying soil would be acceptable.

Site Investigation

Before finalization of the design prior to construction, a more

detailed investigation was commissioned and 6 boreholes were put down in the immediate area of the proposed base building for the Madley 2 antenna. The techniques used were the same as on the original investigation, a shell-and-auger rig being used. Fig. 4 shows a shell cutting tool which, under free-fall conditions, cuts the borehole; this is then lined with a steel tube as boring progresses to prevent the walls of the hole collapsing inwards. At intervals, soil samples are taken, and standard penetration tests (SPT) performed. The test is carried out in the borehole. To do this, the boring cutters are removed and the SPT sampler tool lowered into the hole on the end of a rod. The essence of the method is that the sampler is driven into the ground by the repeated action of a 63.5 kg weight falling through a height of 760 mm. The number of blows required to achieve a penetration depth of 305 mm is known as the *standard penetration number* or N-value. From this value the shear strength of the soil can be determined.

The N-values obtained from the detailed investigation indicated a much weaker stratum under the gravel layer than that indicated by the initial study, and such a result, if proved correct, questioned the foundation's design concept. In view of this, another investigation technique, known as the *Dutch cone test*, was employed. This test does not require a borehole. The cone (Fig. 5) is fitted to the end of a rod which runs within

a tubular sleeve. Both the cone and the sleeve are driven together into the soil by a jacking system. When a test is to be carried out, the cone end is thrust downwards while the tube is held stationary. The resistance to driving the cone forward is measured and from this the soil shear strength is derived. Both the cone test and the SPT are empirical in nature, but a large body of data is available which shows good correlation with results from much more complex and time-consuming techniques, provided that the limitations of the techniques are appreciated and that care has been taken during the tests. The 2 methods are valuable aids for determining the properties of clays, silts and sands. With the cone test, separate boreholes must be sunk to obtain soil samples or to determine groundwater conditions.

On the Madley 2 site, the results of 4 Dutch-cone soundings confirmed the validity of the latest SPT results and showed that the softer material was much less strong than had been expected. This necessitated an urgent review of the foundation's design because of the danger of excessive settlements. The differential-settlement requirement for an earth station's base building is necessarily much more stringent than one for conventional buildings because of the need to maintain antenna performance; for example, in the TRANSMIT mode, the Madley 2 antenna has an angular width of 0.1° between the half-power points of the antenna beam. Therefore, any differential settlement after alignment of the antenna could have undesirable service implications. It was considered that the most likely source of such settlement would be the directional loading imposed on the antenna by prevailing wind. Prediction of likely settlement is often difficult and several theoretical approaches were tried. The results of the calculations did not present a consistent picture, but they indicated that the likely settlements would be excessive; foundation redesign was therefore necessary.

Geology

Fig. 6 shows a typical sequence of strata on the Madley 2 site.



FIG. 4—Site investigation rig showing cutting tool and top of borehole lining tube

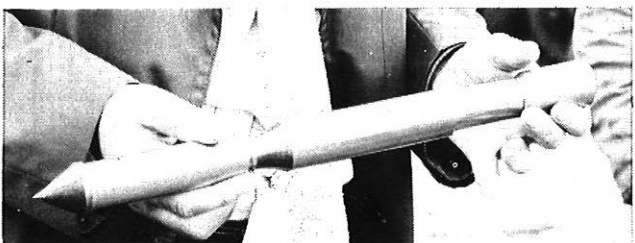


FIG. 5—Dutch cone penetrometer—the test cone

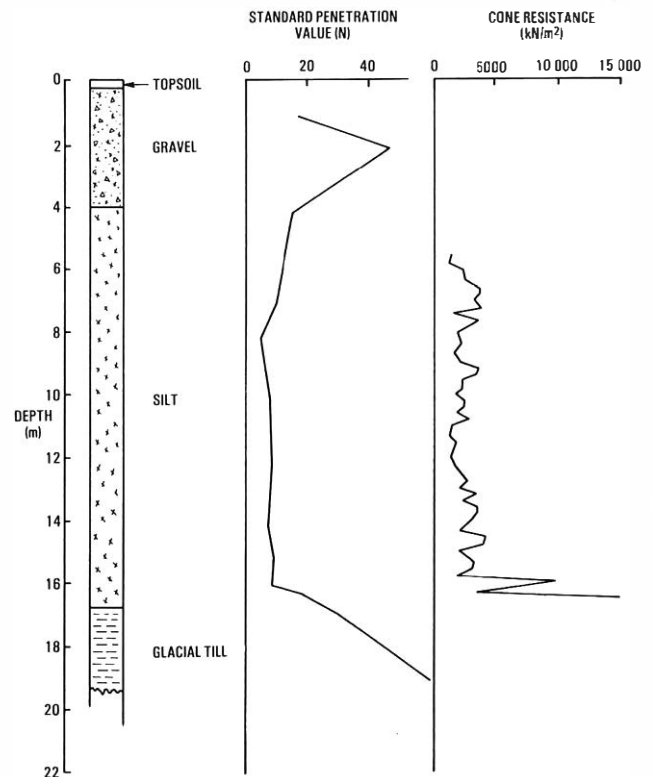


FIG. 6—Madley 2 site. Typical borehole test results showing variation in depth

The uppermost layer is of organic top soil; the next layer is gravel and was probably deposited by high-energy melt-water streams emanating from glaciers during the last period of glaciation. The soft material that gave rise to the main problem for the foundation's design was a silt, probably deposited in quiet water conditions in a glacial lake. Below this was a very stiff glacial till, which is the debris resulting from the mechanical action of the ice of a glacier. The final stratum identified was bedrock, a weathered but very strong and consistent mudstone of Upper Devonian age.

When glacial deposits are identified, the engineer must be prepared for some rapid variations in soils. For example, the meltwater streams are often very active, and channels cut by such meltwater can suffer rapid changes in direction which leave their mark in the geological record. On the Madley 2 site for example, some boreholes indicated substantial lenses of sand within the gravel stratum, while the silty material was far from uniform. However, none of these variations of soil were serious enough to affect the construction work on the site, as the piles penetrated through them to the more consistent soils in the lower strata.

Foundation Redesign

There were 2 possibilities for coping with the weak-silt stratum: one was to use a concrete raft founded in the gravel, as this would spread the loads on the foundation over a much wider area than the ring beam design; the other was to transfer the structural loads down through the weak stratum into the underlying strong material by means of piles, and this was the solution adopted.

Piling

Two main classes of pile are available: the *friction* pile, which transfers loads by friction over its whole length into the surrounding soil; and the *end-bearing* pile, which transfers load into a strong stratum at the bottom end of the pile. The piles used at Madley were of the latter type, the structural loads being transferred into the stiff glacial till and weathered mudstone at depths of about 16 m. Precast reinforced-concrete piles were used. These consisted of 285 mm square section units either 10 m or 5 m in length, with steel connectors at each end of the unit (Fig. 7) which enabled the sections to be joined to give the desired length of pile. The pile driver rig at the stage of augering a hole through the gravel prior to insertion of the pile is shown in Fig. 8; the driving of the pile is illustrated in Fig. 9.

The piles were driven until "refusal"; that is, to the point

where continued driving produces negligible further penetration. The top of the pile was then cut back to enable the reinforcing bars to be connected into the building base beams. In all, 44 piles were used for the antenna.

Prior to the main piling operation, it is customary to test a trial pile to check the validity of the designer's assumptions about the pile's carrying capacity. In the test, the pile is loaded for a long period by means of jacking against some reaction load. At Madley, the conventional kentledge system was used with a jack interposed between the pile's head and the platform carrying the weights (Fig. 10). The movement of the pile with time is recorded (see Fig. 11). Such a test can detect a number of possible pile deficiencies, such as excessive time-

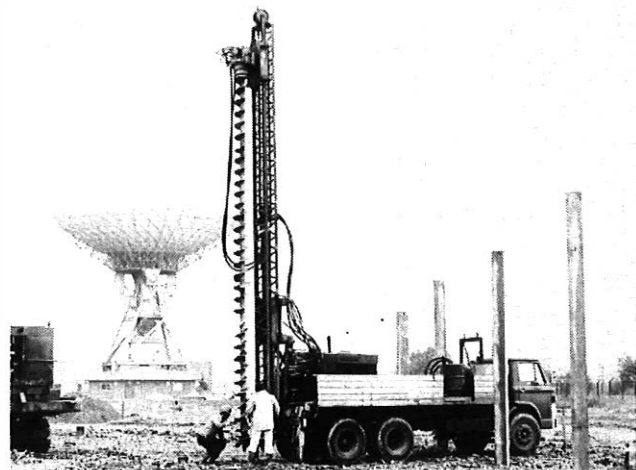


FIG. 8—Augering through the gravel layer prior to pile driving

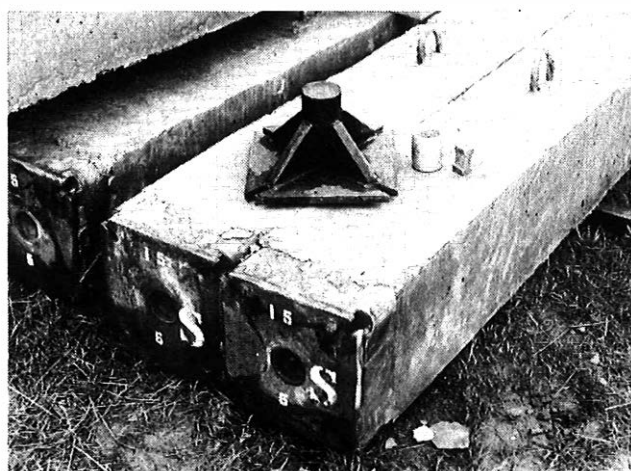


FIG. 7—Reinforced concrete piles

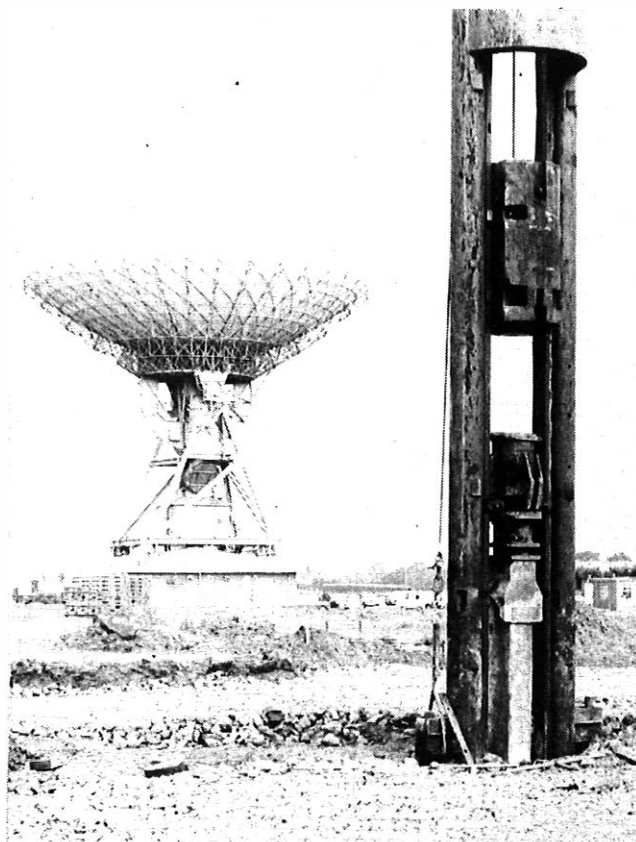


FIG. 9—Pile driving

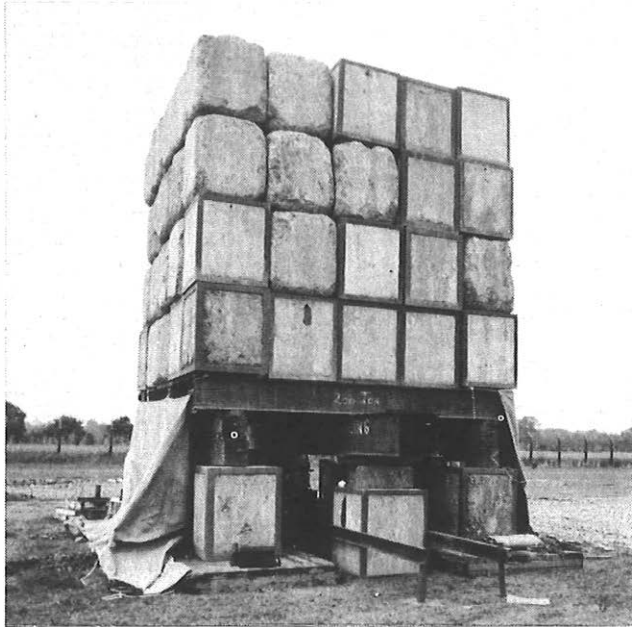


FIG. 10—Kentledge system of pile testing

dependent settlement effects, unseen damage to the pile during driving, and buckling of the pile under load. The latter type of failure could not be ruled out, because the weak silty stratum would give only limited lateral support to the pile.

To the layman, such dramatic changes in design and construction may appear to be very serious, but the civil engineering industry is well adapted to handling such last-minute alterations; usually both site investigation and piling teams can be commissioned at short notice, and very little delay to construction programmes need occur if ground problems manifest themselves.



FIG. 11—Pile testing showing jack positioned between pile and kentledge

PROJECTED OFFSHORE MICROWAVE TOWER

Although this project was ultimately cancelled, this did not happen until all the site investigation work had been completed. The proposal had been to site 2 microwave towers on platforms on, or near to, sandbanks in the southern area of the North Sea in order to establish a line-of-sight microwave link between the UK and Belgium/Netherlands. A knowledge of the sea-bed conditions was critical to the whole enterprise as the total cost of the stations was dependent on the platform's design, which in turn was highly dependent on the foundation conditions.

Geological Study

In such an offshore operation, direct investigation of the soil properties by sinking boreholes is an extremely costly operation. Because of this, it was left to a very late stage in the design study after the project was proved to be feasible in all

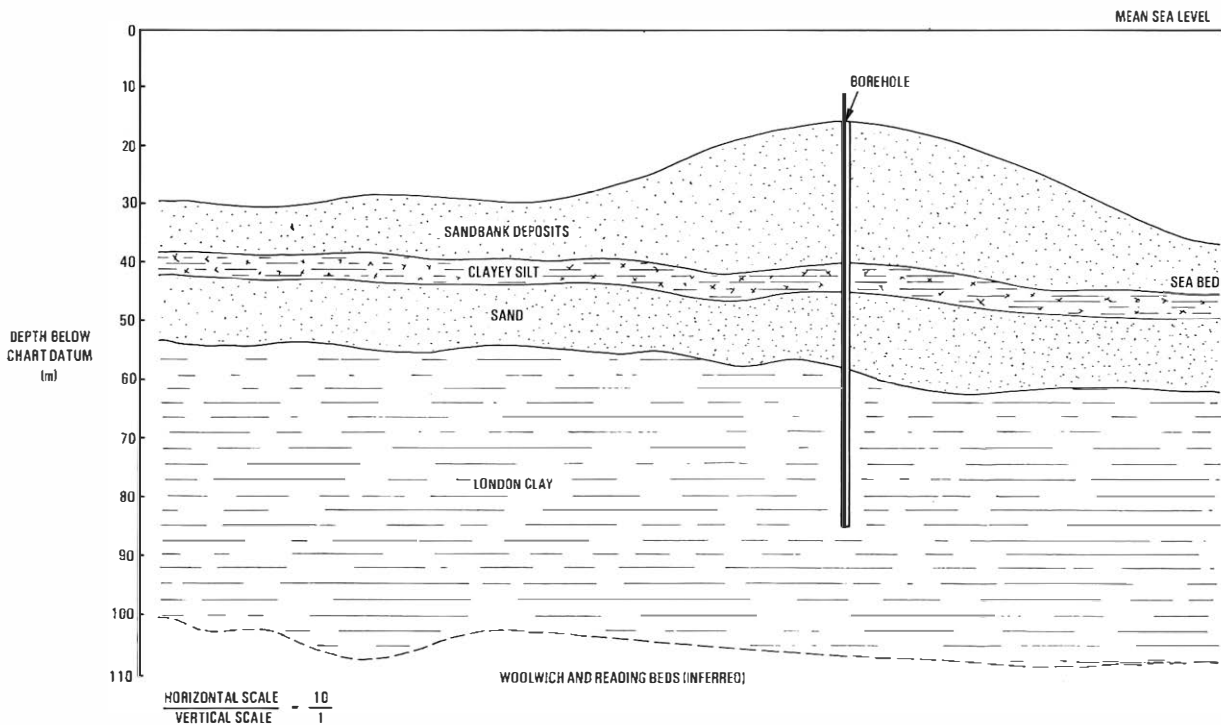


FIG. 12—Typical cross-section through sandbank

other engineering aspects. Reliance was placed on a comprehensive literature survey and evaluation at the preliminary stage of design. It was decided that, if possible, the towers would be sited on sandbanks, as this would greatly reduce the hazard of ships colliding with the structures. Either of 2 basic types of platform could be used: a steel "jacket" which would be supported on piles driven into the sandbank; or a concrete "gravity" structure which would simply sit on the sandbank. Because the final choice depended largely on the foundation conditions, a sound appreciation of the soil conditions was vital at all stages. Consulting engineers were engaged to carry out a literature survey to predict the likely sub-sea ground conditions. In the event, a report was produced which utilized a wide variety of information, including extrapolation of geological data from land bordering the North Sea, the results of a study into a possible use of sandbanks as sites for light towers to replace lightships, and a variety of other published and unpublished data. In fact, the predictions resulting from the literature survey proved to be entirely accurate. A typical cross-section of one of the preferred locations is shown in Fig. 12.

Site Investigation

As the project proceeded, it became necessary to confirm the literature survey results, and to produce detailed geotechnical information on the material in the sandbank and the underlying seabed by exploration on site. The first stage was to determine by means of soundings the surface topography of the sandbank, and then to use geophysical techniques to determine the underlying structure. The techniques used were sonic and relied on reflections of sound-waves from discontinuities such as boundaries between strata. Geophysical methods, however, do not yield data on soil strengths or particle sizes, and to determine these, the most expensive part of the exploration work had to be undertaken. A jack-up barge (Fig. 13) was used which was able to extend its legs down to the seabed to enable the working platform to be lifted above the water level to provide a steady and secure work area from which bore-holes could be sunk (Fig. 14). Thereafter the techniques used were identical to those used on land and included the SPT and Dutch cone penetrometer tests. This operation was dependent on the selection of a suitable "weather window" when sea conditions were likely to be favourable.

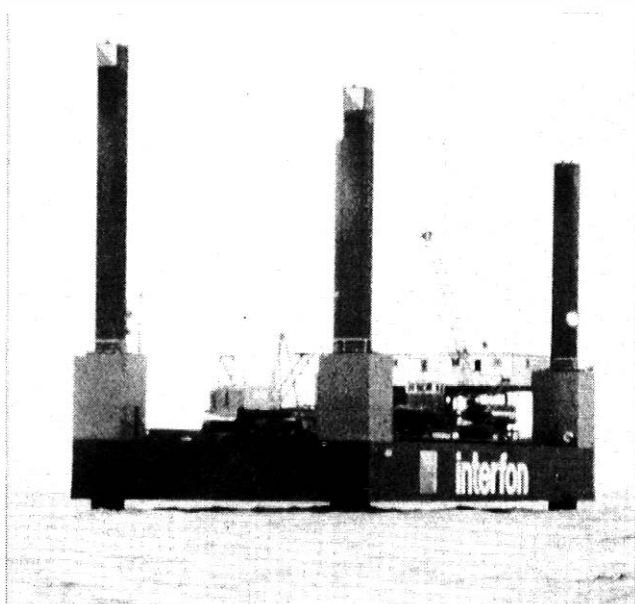


FIG. 13—Jack-up barge positioned over sandbank

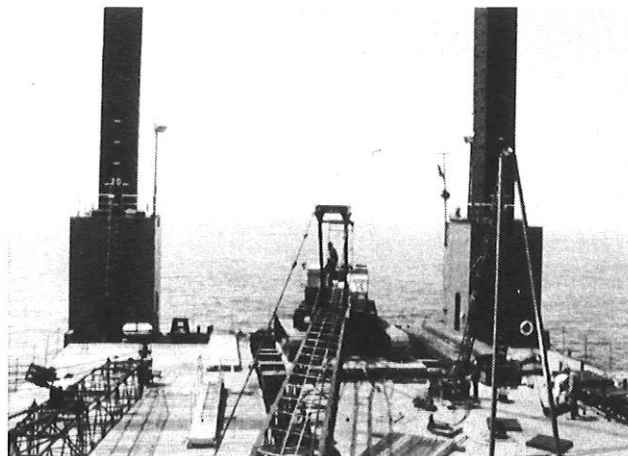


FIG. 14—Working deck of barge

Note: Tripod of site investigation rig on right of picture

Another aspect of the investigation work was the study of the overall stability of the bank; some banks in the North Sea migrate, but others appear to be very stable when checked against old marine charts. In addition, there was the problem of the local stability of the sand at the chosen site because the sand in the top few metres of such banks is typically being continually reworked by tidal currents and storm action.

On completion of these investigations sufficient information had been obtained to proceed to the detailed platform design.

Summary

The severe practical and economic problems of gaining direct access to the offshore site to determine soil properties altered the emphases of the site investigation work as compared to construction on land. There was a much greater reliance on extrapolation from previously published data at the earlier stages than there would have been for a comparable structure on land; nevertheless, the general aims were the same as those for the other examples in this article.

CONCLUSIONS

The case studies that have been discussed demonstrate the close links between geology and engineering design and construction. As has been shown, a knowledge of geology can give invaluable forewarning of possible problems and facilitates the planning of site investigations. It will be appreciated that even the most ambitious programme of test bores or trial pits can survey only a very small sample of the total volume of soil stressed by a foundation. The engineer then must be alert throughout excavation and foundation construction for changes in soil conditions which could necessitate design changes. A comprehensive site investigation may cost no more than 1 or 2% of total costs, but it enables structures which are economic, serviceable and safe to be erected.

The 3 examples discussed are cases where knowledge of the behaviour of soil and rock was obviously needed if the structures were to fulfill their intended function. However, an appreciation of the characteristics of prevailing ground conditions can be equally useful in facilitating many other operations where perhaps qualitative rather than quantitative assessment is more appropriate; for example, construction of duct routes, safe support of the sides of trenches or other excavations, the provision of earth mats or in the search for likely sites for development.

References

- ¹ CLOW, D. G. The Soil as an Engineering Material, Part 1—Soil Properties. *POEEJ*, Vol. 74, p. 122, July 1981.
- ² DUFFY, P. S. J., STREET, M. A., and WING, R. T. E. Selecting an Earth-Station Site. *POEEJ*, Vol. 68, p. 211, Jan. 1976.

Information Technology Year 1982



Information Technology (IT) is the use of computers, micro-electronics and telecommunications to help produce, store, obtain, and send information in the form of pictures, words or numbers more quickly and economically. In order to promote a wide appreciation of the opportunities, benefits and challenges provided by IT to all sectors of the community, the Government has designated 1982 as *Information Technology Year (IT82)*.

IT is a relatively new development, but it is already making significant inroads into a wide range of activities; for example, in industry and commerce, telecommunications, education, health, the media, and the home. Despite the present period of deep and sustained economic depression, the IT industry has become a fast-growing area with huge potential markets. IT offers: the potential for increased business efficiency; the possibility for better decisions; an opportunity to communicate on an individual basis rather than through organized mass; the chance to use technology that makes fewer calls on non-renewable resources; and the prospect of transferring health and education benefits on a scale never before available.

IT82 is a joint initiative by government and business to bring home to people the impact that this new technology will have on their lives. Funding for the campaign has come from both the Government and industry.

The IT82 campaign is aimed at the entire population, but to get the message across, 2 clearly defined audiences have been identified. The first is the general public: children and young people receiving education; the working population who are either users or potential users of IT; and people in their everyday personal lives.

The objectives will be to help these groups to understand the economic and social significance of developments in the IT field, to acquaint them with its uses, to encourage interest and enthusiasm in IT, and, in general, to make them aware of the benefits which IT can bring to every aspect of life. Demonstrations of IT applications will be shown at the open days of large IT users; for example, banks, shops, hospitals and educational establishments. IT will also be featured at large exhibitions (for example, the Ideal Home Exhibition where an IT-equipped home will be on view) and at major outdoor events, and county shows. An exhibition by the Design Council on IT will be taken around the country. Six mobile trailers will also be travelling around the country demonstrating IT in the office environment—the electronic office. This year a series of commemorative stamps will be issued by the British Post Office.

The second audience group is industry, commerce and government. Here the objectives are to encourage the use of IT to help improve efficiency and production and to bring about general awareness of IT products and services available from suppliers in the UK. The IT campaign will use existing business and industry sales conferences and exhibitions as a platform for showing IT at work in a particular commercial or industrial environment. Professional institutions will be encouraged to organize conferences and seminars to educate members about IT. Special demonstrations will be held

within the IT industry and by large IT users, and special training courses for management will be run.

IT82 will culminate in a major IT conference and exhibition which will be held at the Barbican Centre, London, on 8–9 December. The conference, which will be opened by the Prime Minister, will be attended by hundreds of delegates from home and overseas, and drawn from all sectors of the community.

Particular emphasis has been given to nationwide coverage, and to achieve this 9 regional committees have been established to advise on, and co-ordinate, activities on a local level. The entire campaign is being organized from a central project office which will provide a full range of services, including an information centre, support material for regional activities, distribution of materials, speakers for conferences, event calendars, project funding and support for national and regional activities.

At the IT82 launch, Confravision was provided by British Telecom (BT) to mark one of the many ways in which telecommunications and IT are intertwined. Special sound and vision links were provided between the conference room at the Institution of Marine Engineers, London, and the London Telecom Tower. Here the pictures and sound were fed into BT's network, enabling speakers to be seen and heard by journalists assembled in Confravision studios in Bristol, Birmingham, Leeds, Manchester and Glasgow. Special links were also extended from the network to a room in the Europa Hotel, Belfast.

During the conference, journalists at the distant locations were able to put questions to the speakers in the IT Year project as readily as those at the London venue.

Another example of IT is Prestel, BT's viewdata service, which enables users to call up, over the telephone network, information stored on a computer and see it displayed in words and simple diagrams on their television sets.

Prestel, invented by BT, was the world's first IT service to combine the telephone network with television sets in this way when it started in 1979. Some of the latest Prestel sets were on display at the IT82 launch.

In August last year, BT's advanced public data service (packet-switched service (PSS)) began commercial operation to stimulate further progress of IT. PSS is already widely used by more than 100 customers to access specialist computerized databases around the country, and early this year it will be connected to BT's existing international packet-switched service (IPSS). This year, it will give Prestel users a gateway to this wealth of information, and it will speed the cash-less society by simplifying on-line credit verification and electronic funds transfer.

BT will also be introducing at least 2 further IT services this year, the electronic mailbox for business customers, and Teletex, which is a quick and easy way of transmitting text information over the telephone by using communicating electronic typewriters or word-processors.

Further information about IT82 can be obtained from The IT82 Project Office, 19 Bedford Row, London WC1R 4EB.

The Development and Production of the Ambassador Electronic Plan System

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UDC 621.395.61 : 621.395.631.3

In this article, the concepts, facilities, field of use, signalling system and design of the Ambassador electronic plan system are described.

INTRODUCTION

The design principles of a family of commonly-styled instruments—the Ambassador range of telephones—were given in an earlier issue of this *Journal*¹. In that article, a new range of apparatus was described, which had been progressed from concept to high-quality hardware by a series of linked design, development, and production contracts using a main contractor and specialist sub-contractors. It was indicated that to satisfy the criteria of being

- (a) modern in appearance,
- (b) easy to maintain and install,
- (c) designed to enable a simplification of installation wiring and a rationalization of extension-plan arrangements, and
- (d) of high reliability,

three family-related instruments had been developed: a *basic* instrument, a *plan* instrument, and a *facility* instrument.

This article describes the Ambassador electronic plan system (EPS) which is formed by star connecting plan instruments to an electronic control unit. An additional contract for this development was let with the telephone-instrument main contractor because the work required to bring EPS through to the production stage was linked to, and iterative with, the work already being done on the basic instrument; that is, the transmission and signalling circuitry², and the plug, socket and cordage development³.

GENERAL CONCEPTS

As the basic instruments are designed solely for use on simple installations, there is automatically a need for plan instruments and an associated system which can provide at least the facilities offered by the present secretarial/multi-line extension-plan arrangements (plans 1, 105/107, 2 and 2A). It was anticipated that by using an electronic centrally-controlled system, it would be possible to considerably augment these facilities. A system was conceived in which all the stations would have access to all the facilities (unlike the stations of the extension plan 107) and would be 4-wire star connected to a central control unit (CCU). In outline the facilities offered would include:

- (a) exchange line access—incoming and outgoing;
- (b) intercom to all the other extensions;
- (c) hold/transfer; and
- (d) divert.

It was recognized that there was a potentially large market for an easy-to-install simple-to-use low-cost secretarial system of this type, particularly for installations with 1 or 2 exchange lines, and that such a system could usefully be extended to cater for up to 4 or 5 exchange lines (see Fig. 1)—an area in which it would complement the more sophisticated but up-market business systems.

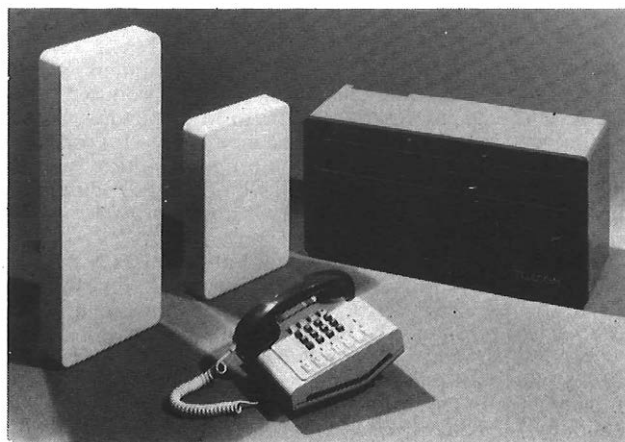


FIG. 1—1 + 3, 2 + 4, 5 + 10 CCUs and plan telephone

THE CONTROL UNITS

In common with all centrally-controlled systems, one of the biggest problems is to achieve cost effectiveness with low numbers of stations or lines, because, in these situations, the cost of the central unit becomes an increasingly significant proportion of the total cost.

The first approach considered was simply to under equip the central unit, the line and station circuitry being provided by using plug-in cards only when required. This approach considerably reduces the cost per station when there are few stations, but when providing a single line, 2- or 3-station systems (previously provided by extension plans 105 and 107) the central unit still has to be of sufficient size to accept the largest system, and thus has to contain all the sockets, guides, back-plane wiring etc., necessary for that system. Consideration was therefore given to the use of purpose-built central units for the low-numbered station and line end of the market. This approach brings with it the advantages of small size and neat appearance (with increased customer appeal) as well as a reduction in the cost—but it does increase the number of items to be installed.

As a result of financial studies of various alternative proposals, it was decided to develop 3 central units (see Fig. 2):

- (a) a small purpose-built unit of sufficient size to control one exchange line only, and up to 3 extensions (1 + 3);
- (b) a slightly larger purpose-built unit to control 2 exchange lines and up to 4 extensions (2 + 4);
- (c) a larger unit, capable of growth by using plug-in exchange-line and station cards, to control up to a maximum of 5 exchange lines and 10 extensions (5 + 10).

† Product Development Unit, British Telecom Headquarters

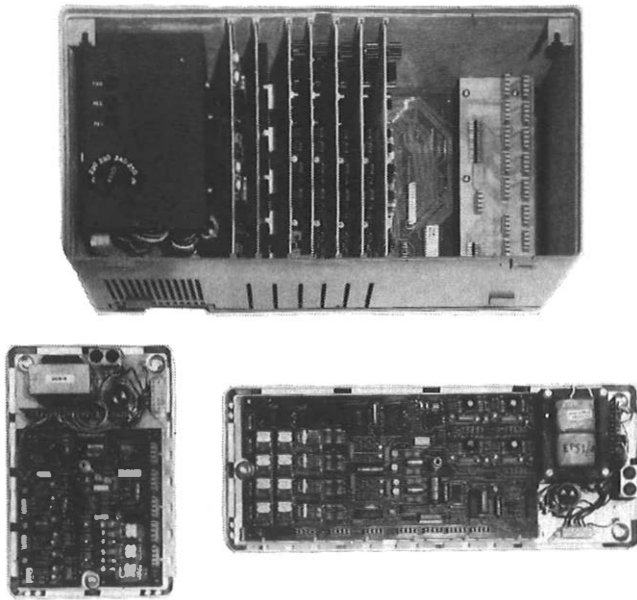
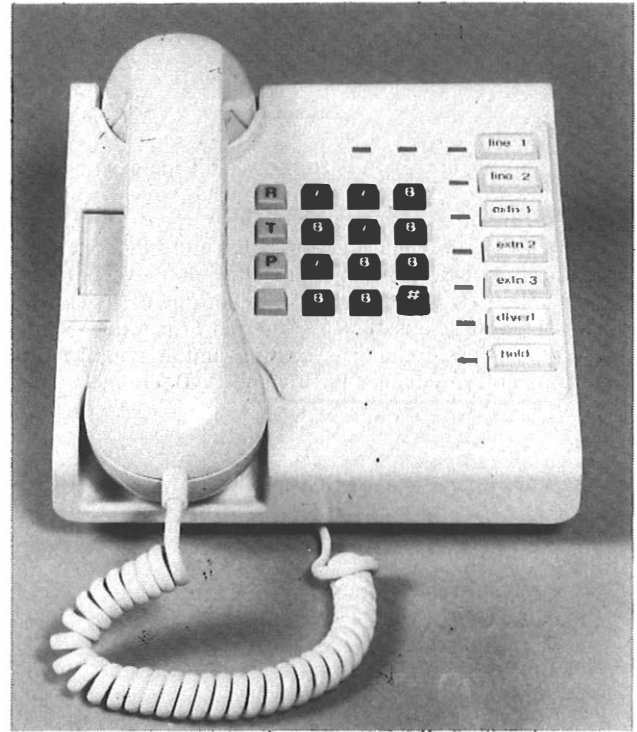


FIG. 2—1 + 3, 2 + 4 and 5 + 10 CCUs with covers removed



Note: Labels indicate instrument is extension 4 of a 2 + 4 system

FIG. 3—Ambassador range plan telephone

THE SINGLE PLAN INSTRUMENT PHILOSOPHY

Although 3 complementary control units (1 + 3, 2 + 4, and 5 + 10) have been developed with each unit capable of handling increasing numbers of extensions, it was considered essential that a common design of instrument should be used throughout the range. This approach not only lessens the cost when changing from one system size to the next—an important consideration for a customer with an expanding business—but also uses the advantages of scale to reduce the unit cost, and minimizes the instrument stocking problems. Also, to keep the instrument cost as low as possible, it was decided to make maximum use of a commonality of design with the basic instrument.

By using the 16-button press-button unit (PBU) (numerals 0-9 plus * and □, and 4 facility buttons), which is standard in the Ambassador basic instrument, the plan-system facilities can all be achieved if all the plan instruments have 7 additional facility buttons which can be:

- (a) labelled or re-labelled on site; and
- (b) locked in the UP position if not required (as can the facility and the * and □ positioned buttons on the standard PBU).

TABLE 1
Button Designations

Button Designation	Dedicated 1 + 3 System	Dedicated 2 + 4 System	Growth 5 + 10 System
Additional Facility Buttons			
1	Line 1	Line 1	Line 1
2	Blank (locked up)	Line 2	Line 2
3	Extension 1*	Extension 1†	Line 3
4	Extension 2*	Extension 2†	Line 4
5	Blank (locked up)	Extension 3†	Line 5
6	Divert	Divert	Divert
7	Hold	Hold	Hold
PBU Buttons 1-9 plus 0	Exchange signalling only	Exchange signalling only	Exchange signalling and Extensions 1-10

* As designated on the Extension 3 instrument
† As designated on the Extension 4 instrument

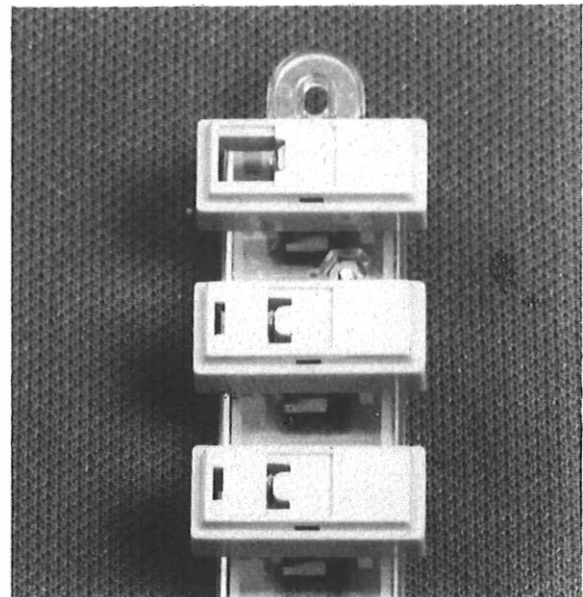


FIG. 4—Facility buttons showing upper button locked in the UP position

These additional facility buttons are provided in a single column which is sited at the right-hand side of the PBU; the usage of these facility buttons and the PBU is shown in Table 1. Fig. 3 shows a plan telephone instrument with labels indicating that it is extension 4 of a 2 + 4 system.

If any extension or line is not fitted, the associated additional facility button is left blank and locked in the UP position at all extensions (see Fig. 4).

It is anticipated that customers will use the exchange number on the line-buttons labels and, on the 1 + 3 and

2 + 4 systems, the extension-users names on the extension-button labels, giving full *direct-named-press-button-intercom* (DNPBI) on the 2 dedicated systems.

FIELD OF USE

The concept of the EPS was to replace all the existing complex, multi-wire extension arrangements which were not catered for by the Ambassador basic instrument. An EPS can be used on direct exchange lines (DELs) and PBX extensions (with or without earth recall) using either loop-disconnect or MF signalling. The EPS can be used, in one of its sizes, to replace extension plans 105/107 (internal or external), 2, 2A, 10, 12, 108, house exchange systems 3 and 4, some key and lamp units and the smaller PMBX and PABX range.

FACILITIES

The facilities offered by the EPS family are listed below:

Basic Facilities

- Incoming exchange-line access.
- Outgoing exchange-line access.
- DNPBI (1 + 3 and 2 + 4 systems).
- Direct press-button intercom (5 + 10 system).
- Lamp indications.
- Hold.
- Enquiry.
- Transfer.
- Divert.
- PBX recall.
- Secrecy (on intercom and exchange lines, except on the intercom of the 1 + 3 system).
- Non-blocking intercom (1 + 3 and 2 + 4 systems).
- Distinctive lamp and buzzer cadences for exchange lines, and for extensions on the 1 + 3 and 2 + 4 systems.
- Click tone on intercom circuit in addition to lamp indication when an incoming exchange call finds all extensions busy.
- Ring tone, and engaged tone (1 + 3 and 2 + 4 systems).
- Ring tone, engaged tone, dial tone, and number-unobtainable (NU) tone (5 + 10 system).
- Secretarial override of DIVERT.
- Lamp indication of secretarial override which remains until cleared—message waiting/executive priority calling (to secretary).
- Extension-programmable exchange-line ringing.
- Extension-programmable divert.
- Automatic barring of repeated diversion.
- Bothway exchange access under mains-failure conditions.
- Flip-up lid with additional-information card.
- All instruments capable of table and wall mounting.

Optional Facilities

Optional facilities can be provided and they are fitted either within the instrument, as an add-on unit, or as a separate wall-mounted adapter. Also, all the additional facilities offered by the basic instrument—recall, 10-address repertory dialler with repeat-last-number, and on-hook dialling—can be made available by using the 4 facility buttons associated with the PBU.

The optional facilities are fitted as follows:

(a) *Within the instrument.*

- 10-address repertory dialler with repeat-last-number.
- On-hook dialling with call monitor.
- Amplified handset.
- Transmitter cut out.
- Inductive coupler.

(b) *As a similarly-styled module that can be mechanically interconnected to the plan instrument to form a composite unit.*

Loudspeaking module—amplifier and loudspeaker (A and LS) No. 12 (Harmony).

Subscribers private meter (SPM).

Repertory diallers—4 types (these repertory diallers are currently under development).

(c) *As a wall-mounted adapter.*

Loudsounding calling.

External-extension working.

Inter-PBX working.

SIGNALLING SYSTEM

Basic Principles

The first decision to be made when considering the type of signalling system to be used was whether to

(a) use data from all buttons: keypad and facility; or

(b) use the standard keypad output, and only use data from the facility buttons.

The latter system was adopted because this removes the necessity for a stand-by battery to give exchange-line calls under mains-failure conditions, reduces the complexity of the signalling system, and enables the standard circuits used in the basic instrument also to be used in the plan instrument. The data signalling then has to provide sufficient signals to control all the required functions; that is, 8 bits (7 keys + gravity switch) inwards, and 8 bits (7 lamps + buzzer) outwards.

The second decision on the signalling was whether to use a synchronous or asynchronous system. To avoid generating timing pulses within the telephone instrument, a serial asynchronous system is used. To do this, and retain a common system for the 1 + 3, 2 + 4 and 5 + 10 units, the system must be capable of sampling the stations within the shortest lamp or buzzer cadence. The use of serial data allows all the extension data inputs to the CCU to be gated to a single input pin of the microprocessor.

Data is interchanged between the CCU microprocessor and each individual extension telephone microprocessor on a dedicated pair of wires running to each extension. The microprocessor in the CCU controls all data transfers by transmitting serial data to each extension in turn, and waiting for serial data to be returned from each extension. The total time taken to transmit and receive the data for all extensions, plus the time for the CCU to perform its control functions, is 65.5 ms. The lamp flashing and buzzer cadences, which are generated by the CCU, are multiples of this period (see Table 2).

Data is transmitted in asynchronous format and synchronization is achieved by preceding it with a start bit (see Fig. 5). Transmitted-data bit periods and received-data sampling periods are generated under software control by the microprocessors at the CCU and the extensions. When the microprocessors are clocked at 470 kHz the instruction cycle time

TABLE 2
Tone and Signalling Cadences

Tone	Frequency (Hz)	1 + 3 and 2 + 4 systems		5 + 10 systems	
		Tone on (ms)	Tone off (ms)	Tone on (ms)	Tone off (ms)
Dial tone	350 + 440	Not provided		Continuous	
NU tone	440	Not Provided		Continuous	
Engaged tone	440	131	131	131	131
Ring tone (buzzer/lamp ringing)	440	262	262	262	262

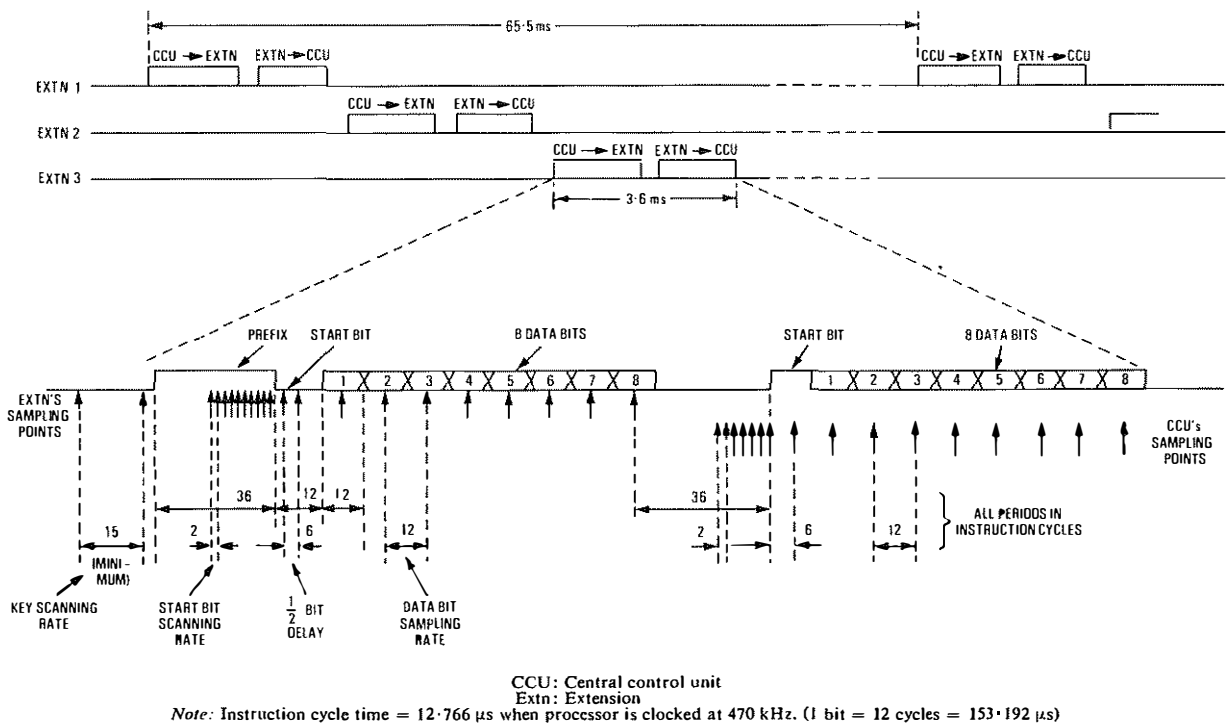


FIG. 5—Serial data timing diagram

is 12.766 μs, and a bit period is chosen to be 12 instruction cycles; that is, ≈ 153 μs.

The microprocessors at the extensions scan the key matrix to detect key depressions and, since they have no interrupt facility, they must also monitor the receiver to detect the start of the serial data from the CCU. Scanning the key matrix takes a minimum of 15 instruction cycles; therefore it would be impossible to synchronize the receive data with a start bit only 12 instruction cycles wide.

To overcome this problem, the following procedure is adopted: the CCU transmits a *prefix logic 1* which is 36 instruction cycles long; this gives the extension time to recognize the start of the data stream. When this prefix is detected, the microprocessor at the extension stops scanning the key matrix and just scans the serial data input, which takes only 2 instruction cycles. After the prefix, the CCU transmits a standard length start bit (logic 0) followed by the 8 data bits. The extension detects the start bit to an accuracy of 2 instruction cycles, delays for a ½-bit period, retests the start bit, and samples the incoming data every 12 instruction cycles. After sampling the 8th bit, the extension delays 36 instruction cycles and then transmits a standard length start bit followed by 8 data bits. No extended prefix is required because the microprocessor at the CCU is now sampling the receive data from the extension and can detect the start bit to an accuracy of 2 instruction cycles. From this point, the CCU data sampling process is identical to that at the extension.

Timing

The time taken to transmit and receive data for one extension is 4 ms, making a total of 40 ms for 10 extensions and leaving about 25 ms for control functions.

In the 1 + 3 and 2 + 4 systems, padding routines are inserted in the CCU microprocessor to maintain the loop time at 65.5 ms.

In under-equipped systems, the CCU still transmits serial data to the non-existent extensions and, when no data is returned within a pre-determined period, the CCU microprocessor inserts a short-padding-routine equivalent which maintains the loop time at 65.5 ms.

Bit Interpretation

Eight bits of data are transmitted from the CCU to each extension and the bits are individually assigned to control the 7 lamps and the buzzer. The 8 bits from the extension indicate the status of the 7 keys and the gravity switch. The RECALL button is also wired to the data matrix and produces 2 bits simultaneously. The assignment of data bits and the key functions are as shown in Table 3.

TABLE 3
Assignments of Data Bits and Key Functions

Bit No.	Key No.	Function (Dedicated System)	Function (Growth System)
1	1	Line 1	Line 1
2	2	Line 2	Line 2
3	7	Divert	Divert
4	Gravity switch	Gravity switch	Gravity switch
5	3	1st Extension	Line 3
6	4	2nd Extension	Line 4
7	5	3rd Extension	Line 5
8	6	Hold	Hold
5 + 6	R	PBX Recall	PBX Recall

Powering

DC power is fed along each data pair to power the microprocessor, lamps and buzzer at each extension. A single diode is used at each extension to protect against data pair reversal on installation. This is followed by a series regulator which controls the voltage and provides a high AC impedance for the data signals. Data is transmitted from a station by modulating the DC power being fed to it from the CCU; and data is received at the station by detecting the presence or absence of a voltage in a given time-slot created by the CCU. The lamp and buzzer are constantly drawing varying currents

from the DC supply, and to prevent these fluctuations being detected as data, all power rails are generated via constant current circuits.

At the CCU, DC power is fed to each pair through a resistor. Transmitting and receiving data is carried out in the same way as at the extensions. Since data is only received from one station at a time, the incoming signals to the CCU can be gated together and applied to a single pin of the microprocessor.

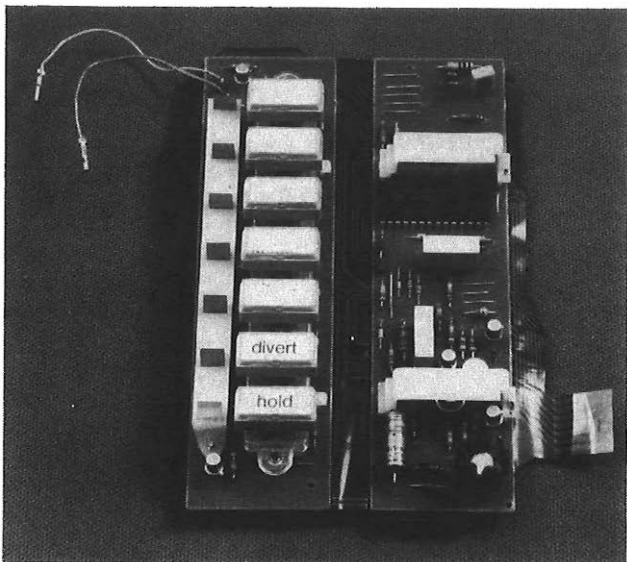
PLAN TELEPHONE

The plan telephone is family related to the basic instrument, having the same end profile and the capability of being mechanically and electrically interconnected to additional modules—Harmony (A and LS No. 12), SPM etc. It consists of a basic telephone with a 7-button/7-lamp (light-emitting diode (LED)) plan module added within the right-hand side.

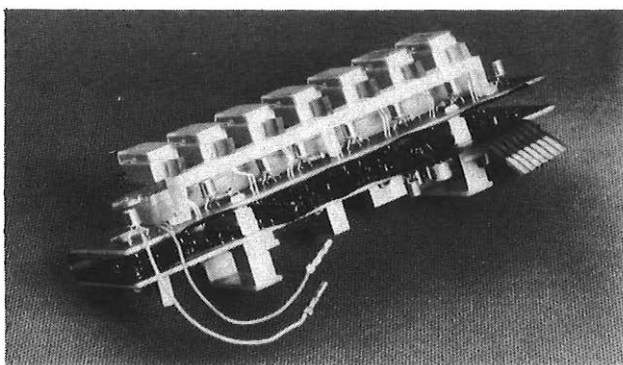
The connexion of the plan telephone differs from the basic version in that the ringer capacitor is put back on the telephone (because plan instruments cannot be connected in parallel), and it is plugged into a secondary version of the line jack³. The wiring is such that the speech is transmitted on one pair of the line cord and the data on the other.

The circuit of the instrument is split into 2 distinct parts: the speech and signalling (loop-disconnect or MF) circuit; and the plan data module. The only interconnexion between the 2 separate printed-wiring boards (PWBs) is the gravity switch, RECALL button, and pins 3 and 4 of the line jack.

Initially all plan telephones will have tone callers for mains-



(a) Unfolded



(b) Folded

FIG. 6—Plan data module

fail exchange-line-call indicators.

The plan data module consists of a 7-switch module with associated LEDs mounted at keypad height and interconnected by flexible tracking to a second, lower PWB which contains the data circuits (see Fig. 6).

To minimize the changes in current drawn by the instrument from the CCU on the data pair, the LED drive circuit works on the principle that while OFF, each LED is short circuited by a transistor which is biased ON, and when required to be lit, the transistor is biased OFF under the direct control of the extension's microprocessor.

The button mechanisms are identical to those used in the keypad but have a longer 24 mm button top. The button top has a removable transparent cover to simplify labelling, and a slider which enables the button to be locked in the UP position if it is not required to be used. This type of button can be locked up without the telephone cover being removed.

Interconnexion

The plan version of the telephone was designed from the outset to accept other units of the same family mechanically and electrically interconnected to it. To enable this to be achieved the telephone has a banana-shaped blanking piece on its right-hand side which is discarded when interconnect is used. The telephone base has 2 square-section holes and 2 locating plugs into which fits a fish plate; this, in turn, fits in an identical manner to the required add-on unit. A U-shaped clamping plate is fitted by 2 screws into the fish-plate between the bases of the 2 units to hold them rigidly together. The electrical connexion between the units can be run through the slot left when the blanking piece is removed and, at the telephone end, access can be gained to the line socket from inside the instrument. When the covers of the units are replaced, a filler piece is fitted between them to give a pleasing aesthetic appearance.

DEDICATED SYSTEMS (1 + 3, 2 + 4)

Both of these systems are microprocessor controlled, with a relay switching matrix. As can be seen from the block diagrams in Figs. 7 and 8, the 2 systems are very similar. The microprocessor program in the 2 + 4 system is larger than that used in the 1 + 3 to cater for the extra exchange line, extension and intercom circuits. The other major difference is that the 1 + 3 system requires one relay per extension in the switching matrix, while in the 2 + 4 system, 3 relays per extension are required.

Central Control Units

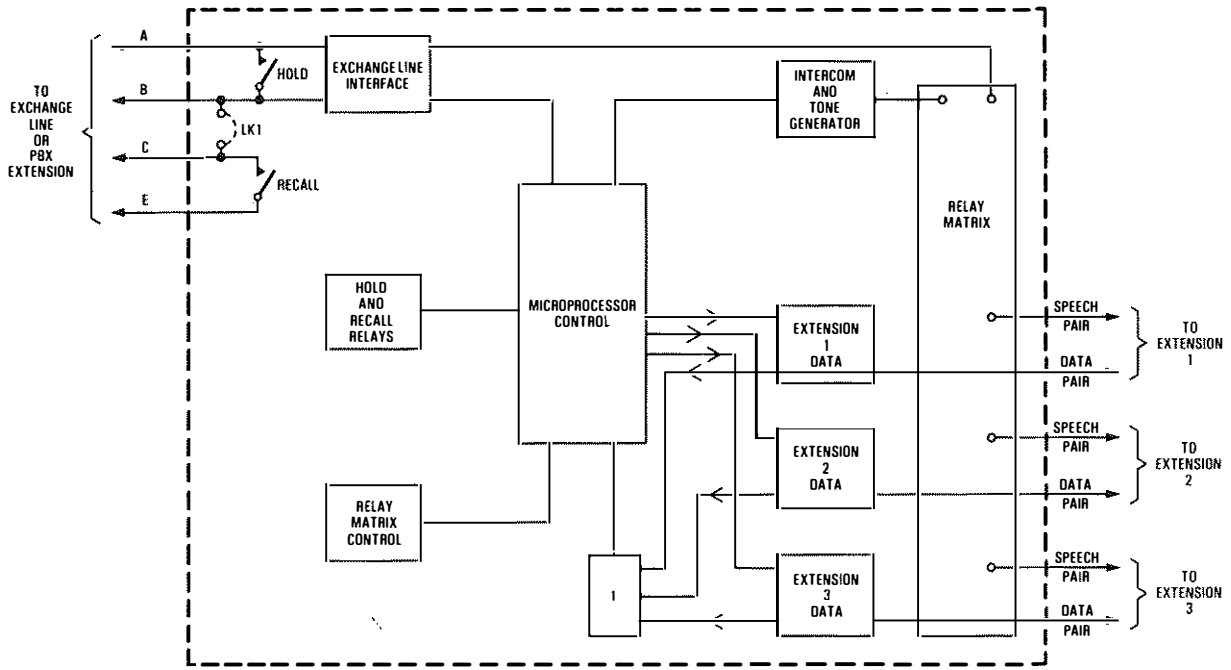
The function of the CCU is best described by explaining how the facilities are achieved.

Incoming Exchange-Line Call

The CCU ringing detector is activated by the *incoming ringing* signal and sends a signal to its microprocessor. The microprocessor sends data to all extensions to flash the LINE 1 lamps at exchange ringing cadence. All extensions that are programmed to receive the *incoming ringing* signal are called via the buzzer at exchange ringing cadence. If all extensions are OFF-HOOK (or in DIVERT) a *click tone* signal is superimposed on the intercom highway to attract the user's attention to the unanswered exchange-line call. An extension answers the call by going OFF-HOOK and pressing the LINE 1 key; the CCU processor recognizes these signals, ceases to send a *buzzer* signal, and continuously operates the LINE 1 lamps in all extensions. It also operates the necessary relays to connect the extension to line 1.

Intercom Call between Extensions 1 and 2

Extension 1 lifts the handset and presses the button associated with extension 2. The *gravity switch* and *button depression* signals are recognized by the CCU microprocessor which



Note: LK1 is connected for earth recall and removed for C-wire signalling

FIG. 7—Block diagram of a 1 + 3 CCU

lights the EXTENSION 1 lamp at all extensions (except 1) and connects extension 1 to the intercom feed by operating the necessary relay. If extension 2 is ON-HOOK, the microprocessor operates the buzzer and lamp at intercom ringing cadence, and returns ring tone to extension 1. If extension 2 is OFF-HOOK, engaged tone is returned to extension 1, but if extension 2 has no telephone connected to it, then no tone is returned. When extension 2 lifts the handset, the microprocessor stops operating the buzzer, stops the ringing tone and connects extension 2 to the intercom highway by operating the appropriate switching relay. It also operates the EXTENSION 2 lamp at all stations (except extension 2).

Transfer of Line 1 Call from Extension 1 to 2

The HOLD button is operated at extension 1 and the CCU microprocessor operates the *hold* relay on line 1, releases the

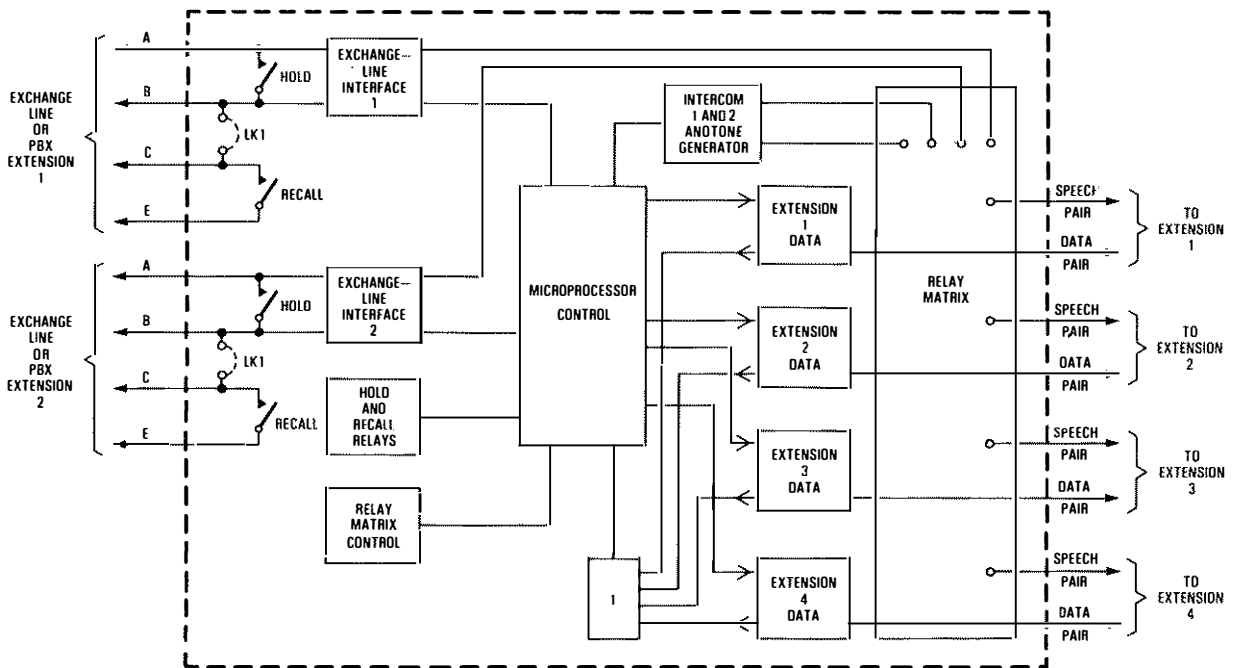
switching relay to disconnect the extension from line 1, and flashes the lamp associated with line 1 at all extensions. Extension 1 then operates the key associated with extension 2, and the buzzer and lamp operate, as previously described.

Extension 2 goes OFF-HOOK and accepts the intercom call, and is asked to pick up the call on line 1. Extension 1 then replaces his handset and line 1 is automatically connected to extension 2 by the microprocessor operating the appropriate switching relays and releasing the *hold* relay.

This transfer can also be activated by extension 2 operating the LINE 1 button and not relying on extension 1 replacing his handset.

Diverting Calls from Extension 2 to 3

Extension 2 operates his DIVERT button and extension 3 has previously been programmed to accept the diverted calls.



Note: LK1 is connected for earth recall and removed for C-wire signalling

FIG. 8—Block diagram of a 2 + 4 CCU

The microprocessor examines its program to determine which is the nominated extension and whether it is free to be a divertee (for example, is not already in DIVERT). The DIVERT lamp at extension 2 is operated and the nominated lamp at extension 3 is operated. For an incoming exchange-line call, the same procedure as previously described applies, but to extension 3 whose DIVERT lamp flashes in cadence with its buzzer. The buzzer at extension 2 does not operate.

THE GROWTH SYSTEM (5 + 10)

The largest of the 3 systems is very similar in circuitry to the smaller versions, but some minor operational changes are made to cater for the additional number of exchange lines and extensions. On this system, the first 5 buttons on the telephone are dedicated to the exchange lines, and the keypad buttons are used to call the extensions. This means that, while on the dedicated systems, either loop-disconnect or MF signalling telephone can be used with equal facility depending upon the exchange line termination, on the growth system, the intercom circuits must be capable of taking keypad information and converting it for use by the microprocessor. Hence 2 distinct intercom circuits have been developed; one for use with loop-disconnect telephones, and a second for use with MF-signalling instruments. The loop-disconnect intercom card contains a counter to convert the pulses to a 4-bit code plus strobe to feed into the microprocessor, and operate the switching relays. The MF intercom card contains a simplified MF detector which does a similar conversion.

CUSTOMER PROGRAMMING

Customer programming has deliberately been kept to a minimum to avoid confusion. Two particular facilities can be set by the customer from his individual terminal—exchange-line ringing, and divert.

Incoming exchange-line calls can be programmed to ring, or not, a particular terminal. This is done with the telephone handset ON-HOOK by pressing the HOLD button and the lamp associated with the exchange line will light. This indicates that the buzzer will sound to an incoming call on that line. To change its state so that it will not sound to an incoming call the LINE button is pressed and released, and the lamp will extinguish. This can be done in turn for all exchange lines.

The programming of the DIVERT facility differs slightly on the 1 + 3 and 2 + 4 from the 5 + 10 system. On the 2 smaller systems where DNPBI is used, the programming is done ON-HOOK by pressing the HOLD and DIVERT buttons together and, while these are held down, pressing the button associated with the extension to which calls are to be diverted. All 3 buttons are then released. The facility is then invoked by simply pressing the DIVERT button and noting that its associated red lamp has lit. A green lamp lights on the divertees instrument.

On the large system, a different procedure has to be used because the keypad (0-9) cannot be used for this purpose. Programming is achieved by pressing the HOLD and DIVERT buttons as before, but with LINE 1 to LINE 5 buttons representing extension 1-5. To program divert to extensions 6-10, the HOLD and DIVERT buttons are pressed simultaneously, the DIVERT button is released, and the LINE 1 to LINE 5 buttons now represent extensions 6-10.

ADAPTER UNITS

It was decided that if increased fields of use or extra facilities were required, an additional adapter (or adapters) would be fitted. This philosophy enables the cost of the basic package to be kept to a minimum—only those customers requiring the extra facilities have to pay the extra cost.

External Extension Adapter

An external extension adapter was developed to enable a

2-wire telephone to be used with some slight reduction in facilities. Basically, the adapter, which is fitted near the CCU, converts loop-disconnect pulses from the 2-wire telephone into data signals acceptable to the CCU via the data pair. The external extension has no programming facilities, hence it cannot divert. Exchange-line programming is done on an all-or-nothing basis at the adapter base by a single button. An earth button at the 2-wire telephone is used to provide the HOLD facility, although this is not fitted if the EPS is connected as an extension of a PABX with earth recall. The external extension is normally fitted in place of the last extension on the EPS.

Inter-PBX Adapter

For systems that require a direct connexion to a remote PBX and to retain its own exchange line capability, an inter-PBX adapter was developed. This also replaces one extension on the system (normally the last) and provides SSDC5 signalling to and from the PBX. Again, because the extension on which the inter-PBX adapter is installed cannot be programmed, a button is provided on the inter-PBX adapter unit in the same way as an external extension.

Loud-Bell Adapter

To cater for customers for whom a buzzer signal at the instrument is insufficiently loud, a bell adapter was developed. This is fitted on a per station basis on the CCU side of the telephone jack. A single strap is changed in the telephone instrument and the buzzer signal is diverted to operate a mains driven ringing supply. This can be used to ring the telephone tone caller (over the speech pair) and/or an external loud-sounding bell.

CONCLUSIONS

This extension of the joint BT/British Industry development of the Ambassador range of telephone has produced an electronic plan system which, by using dedicated instruments and 2 pairs of wires star connected to an electronic central-control unit, has eliminated the need for the multi-wire systems previously required for the secretarial-type extension-plan arrangements. The plan instruments, in conjunction with this system, can be used on DELs and PBX extensions, which in turn, with the addition of adapter units, can also be used on external extension and inter-PBX circuits.

Quantities of these simple-to-install easy-to-use low-cost dedicated systems have been ordered (25 000 1 + 3 systems and 5000 2 + 4 systems, which require some 70 000 instruments); trials have already commenced in the North Eastern Region and the South Western Region of BT.

The development of the growth system (5 + 10) has also been completed and small quantities of this system have been ordered to enable a pilot trial to take place. It is anticipated that this trial will be starting in March 1982.

ACKNOWLEDGEMENTS

The development and production engineering of the Ambassador electronic plan system was carried out for BT by GEC Telecommunications Ltd. The authors wish to thank all those involved in this project, both in Industry and BT, for all their efforts.

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Power Supplies For Small Telecommunications Centres

Part 2—AC Power Plant No. 440

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UDC 621.311: 621.395.721

This 2-part article describes the new DC and AC power plants that have been developed primarily for small local exchange modernization; they can also be used for other applications within the public switched telephone network. The first part of this article outlined the power requirements for modern small telecommunications centres and described the new DC Power Plant Nos. 235 and 236. This second part describes a new range of standard 240 V single-phase AC stand-by plant designated Power Plant No. 440.

INTRODUCTION

The British Telecom (BT) public switched telephone network (PSTN) comprises over 6000 telecommunication centres of which almost half are small rural exchanges with less than 600 connexions. As described in Part 1 of this 2-part article¹ on power supplies for small telecommunication centres, these exchanges have relied largely on a 24-hour battery reserve in the event of mains failure. With the change from Strowger to electronic equipment, and the corresponding increase in the standing power load, the battery capacity would need to be substantially increased to provide the same level of reserve. However, a new standard dual-reserve power plant, which provides adequate energy reserve using DC power plant and a one-hour reserve battery (as described in Part 1 of this article), together with an automatic AC stand-by plant designated *Power Plant No. 440*, has been introduced.

OPERATIONAL PLANT DESIGN

The new AC power plant needed to support the DC Power Plant No. 235 requires 2 sizes of engine/generator set, 6 kVA and 10 kVA, supplying single-phase 240 V at 50 Hz. Table 1 shows the relative output ratings of the power plants.

The AC power plant is required to be fully automatic, and run unattended for up to 30 days.

An important feature of the rural telephone exchange equipment modernization plan is the retention of the existing buildings, where possible; the new power plants would have to be housed somewhere in this accommodation. Before embarking on a completely new design of AC plant, extensive surveys of typical rural exchanges were undertaken. Had it been found possible to scale down the existing range of BT packaged engine/generator sets, AC Power Plant No. 426²,

the design of the rural AC plant could have been simplified. The survey proved the task to be more complex than first envisaged because the existing buildings varied considerably both in layout and type of construction.

For the plant to be installed easily by local staff with the minimum of work prior to installation, the equipment must be able to pass through a standard 1970 mm × 760 mm doorway, without major dismantling; all fixings had to be confined to walls and floor, as the ceilings could not be relied on to take heavy weights. Also, the engine sets would, in some cases, need to be acoustically treated to meet acceptable noise levels at the boundaries of the sites.

ENGINES

At low power levels, the diesel engine is not the predominant commercially-available prime mover and consideration was given to engines using other fuels. Petrol and liquid-petroleum-gas (propane) engines appeared to have a capital-cost advantage, but security risks attached to the use and storage of highly-volatile fuels prohibited further consideration. At the ratings mentioned, the air-cooled direct-injection 4-stroke compression-ignition diesel engine, running at 1500 rev/min proved the most economic choice. These engines are of the heavily-finned cylinder block and detachable-head type and constructed in cast iron, with cooling provided by a cowled-flywheel fan. The pistons are of aluminium alloy with toroidal bowls set in their crowns. The forged steel crankshaft is supported on thin-walled steel-backed bearings coated in aluminium tin. Lubrication oil is pressure fed to the main, large-end, and valve-rocker-shaft bearings, but the cylinders, small ends and camshaft are splash lubricated. The fuel pumps are operated by a rocker-arm gear from the camshaft.

ALTERNATORS

In line with present practice, the alternator used is of the rotating-field brushless type and has an automatic solid-state voltage regulator. Although waveshape distortion cannot be eliminated, especially in small alternators, harmonic distortions were minimized by the use of skewed stator slots and by operating at lower flux densities than commercially-rated machines. In selecting these machines, extensive tests were undertaken to assess their performance when supplying power to transducer- and thyristor-controlled rectifiers. At the early stage of testing, problems were encountered with false tripping of the alternator frequency monitor, Detector No. 1A, which

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TABLE 1
Power Plant Ratings

Power Plant No. 235 DC Output Rating	Power Plant No. 440 AC Output Rating
10 A } 20 A } 40 A }	6 kVA
80 A	10 kVA

relies, in part, on counting the zero points in the voltage wave against a reference frequency. Observations of the voltage wave showed sharp dips at varying intervals coinciding with the firing of the thyristor controller in the load rectifier. These dips, although short in duration, were enough to cause false readings in the frequency monitor. A simple resistor/capacitor filter fitted to the input of the DC Power Plant No. 235 rectifiers overcame the problem.

ENGINE/GENERATOR SETS

The final designed unit comprised a close-coupled engine/generator set mounted on steel-spring anti-vibration mountings attached to a skid base. This type of mounting gives a high degree of isolation from engine vibration and eliminates the need for floor fixing bolts. The set can be raised using jacking points to enable machine-mover skates to be placed under the skid frame which can then be easily moved to any required position. The lubrication-oil supply is drawn from the engine sump or reservoir, depending on the make of engine and, if the capacity of the sump is inadequate for extended running of up to 30 days, an additional tank is provided within the base frame.

The external exhaust system connects to a rigid support frame, mounted centrally on the base frame. An expansion/anti-vibration bellows connects this point to the engine exhaust manifold.

The engine cooling-air outlet is fitted with a stub duct to enable a flexible connexion to be made when the set is not acoustically treated.

Two electrical switching sensors are fitted to detect low oil pressure and high air/oil temperature and are wired back into the control cubicle.

Engine starting is by means of a 24 V DC motor of the coaxial type, fitted with pinion abutment sensing.

The automatic voltage regulator and all the electrical connexions are grouped together, and kept as far away from the fuel and lubrication pipes as possible. Fig. 1 shows a 10 kVA engine/generator set.

EXHAUST SYSTEM

In present engine installations, 2 silencers are used. The

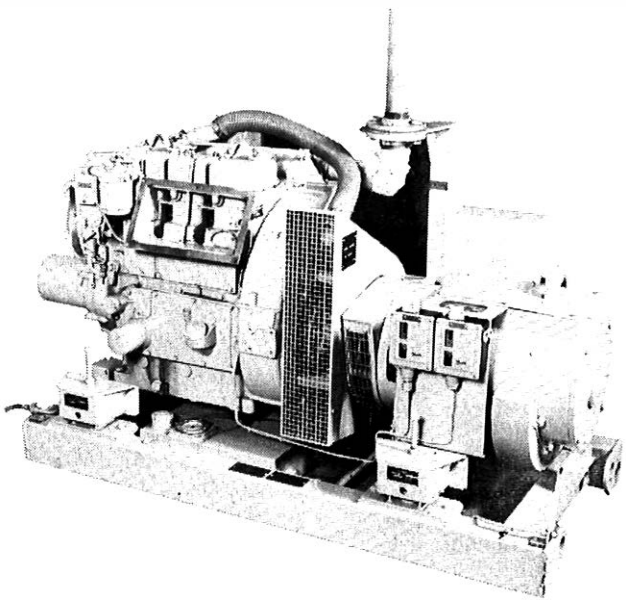


FIG. 1—Typical 10 kVA engine/generator set

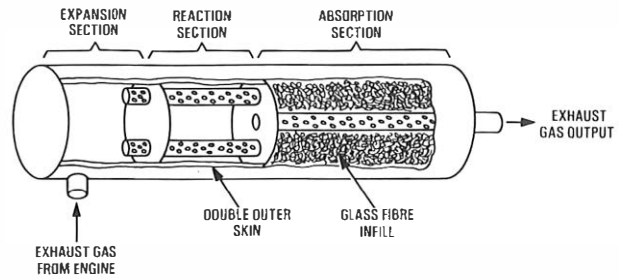


FIG. 2—Combined silencer

primary one forms part of the engine, but the secondary silencer is usually fitted with its associated pipework to the external face or roof of the building. This latter installation is expensive, and in rural settings would present many fixing and aesthetic problems.

The development of a combined silencer (see Fig. 2) overcame most of the difficulties. The combined silencer is made up of expansion and reaction sections, to attenuate low-frequency noise, and an absorption section which deals with the higher spectrum. The finished production unit proved to be cheaper than the cost of the method using 2 silencers.

The complete exhaust system is designed in kit form, and comprises various lengths of pipe, the silencer and a fixed wall anchor plate. As the external discharge point may vary with site requirements, special bends are provided to allow for variation of discharge configurations. The exhaust system is self supporting and no overhead fixing is required. Support is by means of the engine/generator support frame and the external wall fixing. This allows for the exhaust to be fixed in any external wall radially around the engine location. On completion, the pipes are fitted with preformed lagging, and the silencer is provided with its own detachable heat-insulating jacket.

COOLING-AIR OUTLET

A flexible steel-reinforced impregnated-glass-cloth duct enables existing ventilation apertures to be used or permits outlets to be cut in an external wall without the need for precise positioning. Care is required to minimize the transmission of engine noise and, in consequence, the outlet duct is fitted with an internal acoustic attenuator designed to reduce engine noise by 36 dB(A) at the outside face of the building.

AIR-INLET LOUVRE UNIT

In accommodation not provided with sufficient natural ventilation to cope with engine running conditions, a small solenoid-operated air-inlet louvre unit is available. Fig. 3 shows the air-inlet louvre unit.

FUEL STORAGE SYSTEM

Fuel is supplied to the engine, by gravity, through a flexible pipe connected to a single all-welded rectangular bulk-storage tank mounted on a support stillage. The tank is fitted with fill, overflow and drain-down pipes connected to an external fuel-fill point. A contents gauge is provided and this can be fitted on the tank or at the fill point. The lower part of the stillage is fitted with an integral drip tray. In most installations the tank would be fitted adjacent to the engine set.

In a few instances where bulk storage of fuel may be available, a small service-tank stillage has been designed with an automatic top-up pump and level-alarm switches.

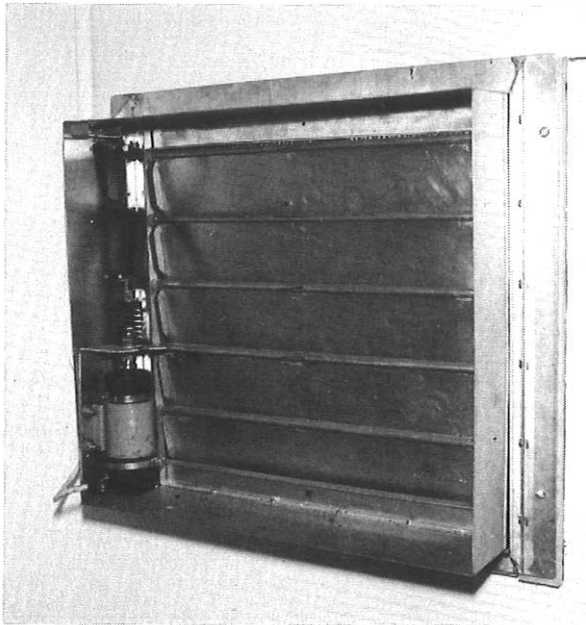


FIG. 3—Small solenoid-operated air-inlet louvre

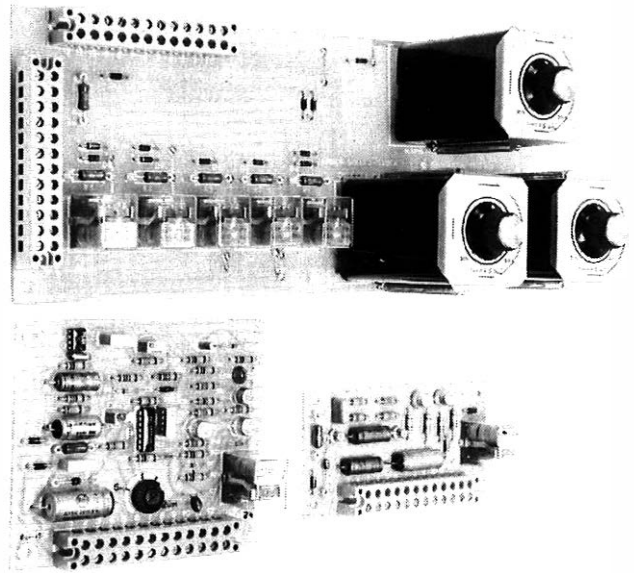


FIG. 4—Control, battery-voltage and repeat-start PWBs

CONTROL UNIT

The plant requirements are to monitor the mains supply and provide, after a timed period of failure, automatic starting of the engine set. In existing BT plants, this period is 5 s to allow for transient fluctuations, but national statistics on mains failures show that, in rural areas, the majority of these are of a longer duration. To overcome unnecessary starting of the engine, the delay is set at 30 s. Similar delays are incorporated to allow the engine to start and warm up before taking load, and also to ensure the mains supply is fully restored before switching back.

In deciding on a new design of control system, care had to be taken not to dismiss the well proven relay logic used on existing plants. It was tempting to reduce space with an all solid-state controller, but previous experience with high-current solid-state switching had proved unreliable and so a hybrid arrangement was decided upon. Future developments will, however, include a microprocessor-based controller, which is now undergoing evaluation.

The unit consists of a basic printed-wiring board (PWB) with miniature relays as the operative interface to the main BT standard monitors and detectors used on existing AC power plants. The mains/alternator monitors are Detectors No. 31B, and the alternator-frequency monitor is Detector No. 1A. The repeat-start unit has been modified from the standard system and only the battery-voltage monitor has been specifically designed; this has a delayed operation from 0 to 20 minutes to prevent a false alarm over the engine-start period. This new monitor is the Detector No. 38A. Fig. 4 shows the control, battery-voltage and repeat-start unit PWBs. The block diagram of the control system is shown in Fig. 5. Timing of the control functions is by means of 30 s plug-in timers. The final configuration is a quarter of the size of the conventional relay-logic system used on the AC Power Plant No. 426.

In the main current-carrying circuits, the components and cables are rated for a maximum of 50 A. All the electrical components are housed in a rigid steel cubicle divided into 2 compartments. The lower half contains a standard DC power plant Rectifier No. 151 used to maintain the control/starter battery in a fully-charged condition. The top section contains the control and switching equipment. Use is made of the front hinged cover for instrumentation, alarm lamps, and control switches (see Fig. 6).

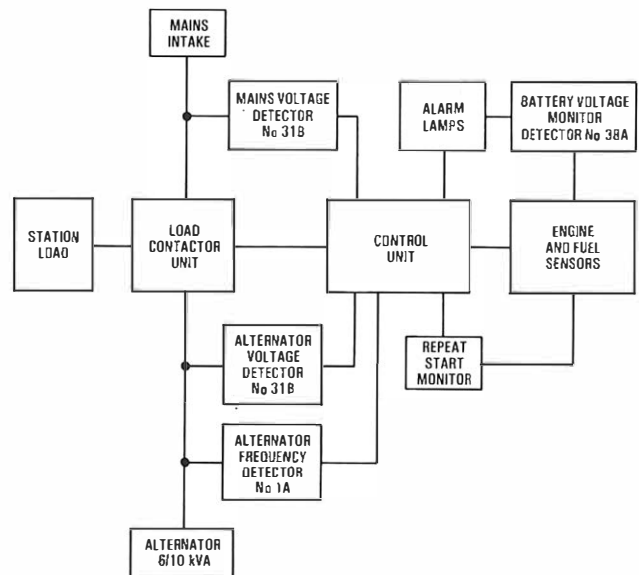


FIG. 5—Block diagram of the power-plant control

Instrumentation is kept to a minimum with only a voltmeter, switchable to mains or alternator, and an ammeter connected to the load side of the cubicle. A small tripping meter is included to record the number of engine starts.

The alarm channels are provided for the following conditions:

- (a) High engine temperature.
- (b) Low oil pressure.
- (c) Low engine speed.
- (d) Alternator voltage out of limits.
- (e) Low battery voltage.
- (f) Control fuse failure.
- (g) Engine on load.
- (h) Maintenance attention.

All alarms except *maintenance attention* and the engine on load are held until manually reset.

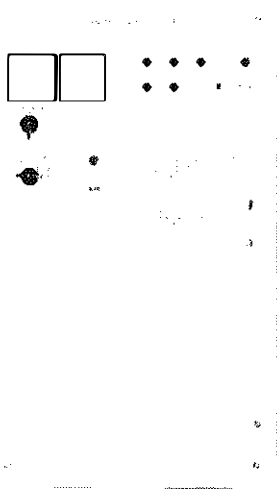


FIG. 6—Front view of the control cubicle

In the operation of a coaxial starter, there is a low probability that the moving pinion will not mesh with the startering teeth on the flywheel before full power is applied to the motor. To avoid abutment and motor damage, a repeat start monitor is fitted; the unit waits for a *pinion-fully-engaged* signal, and if it is not detected within 1 s, the starter is de-energized and then re-applied.

The final control function is to lock out the start sequence after 30 s if the engine/generator monitors fail to signal healthy running conditions. After such an operation, the mains contactor remains closed and awaits the restoration of the mains.

POWER DISTRIBUTION UNIT

This unit connects between the load and the power plant as shown in Fig. 7. The rotary *BYPASS* switch enables the control unit to be disconnected from the incoming mains supply and alternator output, for maintenance. In this switch position the mains supply is fed directly to the load.

ACOUSTIC CANOPY

At the beginning of this project it was known that, in light-weight-constructed buildings, additional noise attenuation would be necessary to achieve the standard, for engine stand-by plant, of maintaining an ambient noise level of 42 dB(A)† 4 m from the building. The true extent of the problem had not been clearly established, but the necessary information was determined by simulating engine noise by recordings played through loudspeakers mounted in a typically operational position in the building under test.

Fig. 8 shows the results taken outside a wooden building when a 6 kVA engine noise was simulated. The final results showed that, in the worst case a timber building housing a

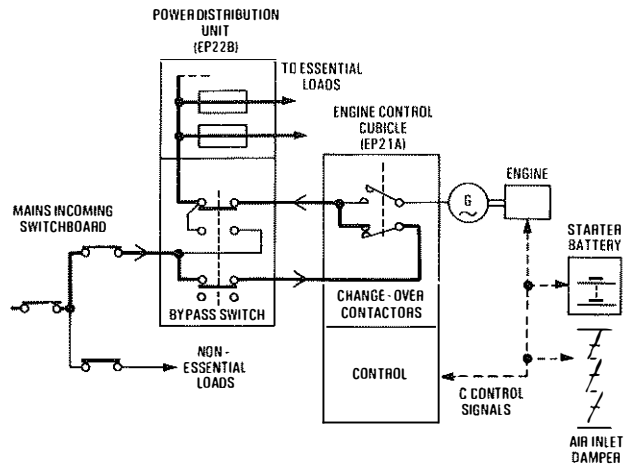
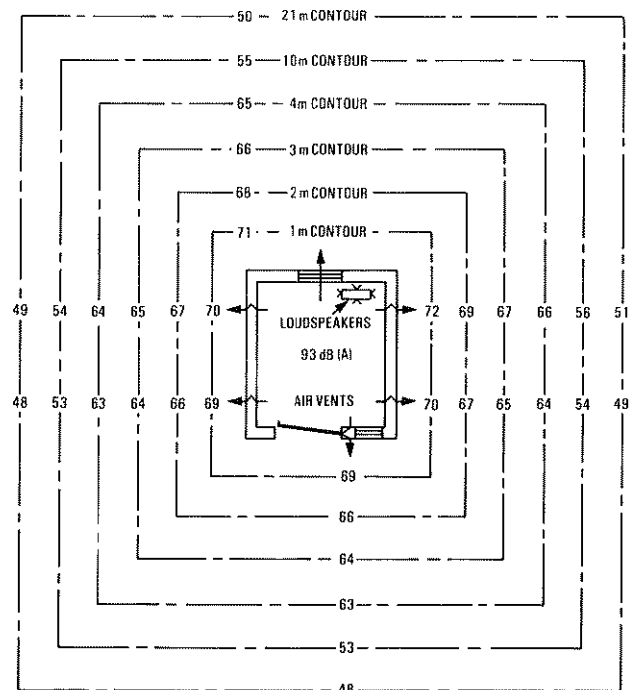


FIG. 7—Load connexion diagram



Note: Results are shown as noise levels (dB(A))

FIG. 8—6 kVA simulated engine-noise tests in typical timber building

6 kVA or 10 kVA machine, an additional attenuation of 20 dB(A) would be necessary to avoid noise disturbance to neighbouring properties. The most economic method of achieving these results was to design an acoustic canopy to go around the engine/generator set, without impeding its performance. This was achieved by producing a sound insulating housing made up of easily detachable modules fabricated in rigidized aluminium lined with glass fibre, later replaced with a flame-retarding plastic-foam sheeting. In the finished construction, the panels are placed around the set and held with clip fasteners. Figs. 9 and 10 show a typical canopy arrangement and an installation fitted with an acoustic canopy.

The incoming cooling-air movement relies on the engine and an uprated alternator fan (to match the engine fan pressure) to draw air into the housing via ducts connected to acoustic attenuators built into sections of the canopy. Special

† dB(A) measurements are those recorded in the "A" weighting scale which is widely used to measure human subjective reaction to noise

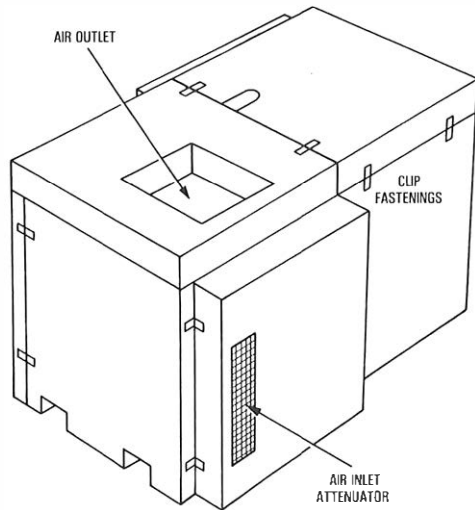


FIG. 9—Acoustic canopy layout

cut-out sections are provided for cabling, fuel and exhaust connexions. Final test runs have shown the noise attenuation to be better than the design specification.

CONCLUSION

Since the initial development and experience gained from laboratory prototype models and early installations, the Power Plant No. 440 has met its design parameters of being simple to install, compact and relatively cheap to install. The next phase of development will be in the 3 kVA range of outputs and consideration will be given to the use of high-speed (3000 rev/min) diesels.

ACKNOWLEDGEMENTS

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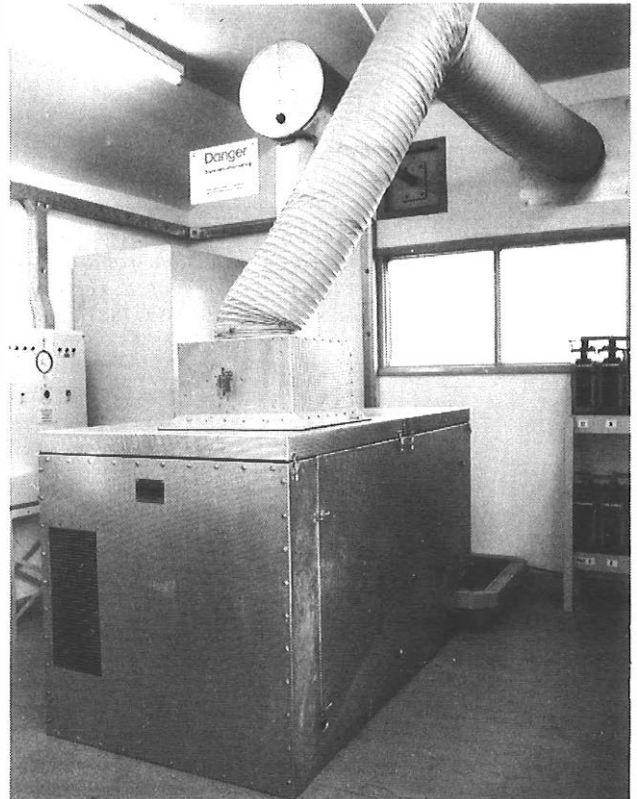


FIG. 10—Early design of acoustic canopy housing on 10 kVA engine/generator set

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Teletraffic Aspects of Processor Utility Design

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UDC 621.395.31: 681.31

In designing a practical processor utility subsystem, due account should be taken of the teletraffic implications of each design decision made throughout the design process. The basic system philosophy should take into account every possible traffic condition which could conceivably arise in practice, if a resilient and economic system is to be developed. This article examines the work-load generated by telephone traffic for an exchange processor and discusses the design implications, with emphasis on the problems of load control.

INTRODUCTION

Teletraffic engineering must play a part throughout the design, development, and implementation of a switching system. During the early research and design phase, many design options need to be examined in order to assess the effect of their general teletraffic characteristics on the system's traffic-carrying capabilities, thus ensuring that the best design options are chosen for development. Throughout the development phase, the emerging product needs to be assessed in order to optimize the design and to give confidence in the system's capability. When the developed system is implemented in the field, dimensioning rules are needed, the relationship between traffic and equipment quantity being determined by teletraffic modelling and analysis.

This article discusses some of the teletraffic aspects involved in the research and design phase of a switching system's processor utility. If these aspects are neglected, the processor utility may be found to contain undesirable bottle-necks which limit its throughput or result in a poor overload characteristic. Additionally, the practical switching system may be vulnerable to changes in the traffic offered, creating disorder in the rest of the network through its improper or inadequate reactions.

PROCESSOR UTILITY DESIGN CONSIDERATIONS

In any practical switching system design, the processor utility can be realized as a centralized system or as a decentralized, or distributed system. The latter can consist of micro-processor-based processing elements forming a loosely-coupled multiprocessor. In deciding how such elements should communicate, the partitioning or functional splitting of work has to be assessed on teletraffic and reliability grounds, as does the general interconnexion strategy. There are many ways in which processing elements (PEs) can be interconnected for a telecommunication application; for example, the options of ring, point-to-point etc. These, and the many possibilities for hierarchical communication structures, need to be compared when loads which might occur in a switching-system environment are carried. For any PE interconnexion strategy, communication protocols have to be derived and potential areas of resource contention identified before fundamental structures are irretrievably defined.

Only if the final applications are considered at the outset will a chosen design be efficient, reliable, and cost effective when placed in the live network.

Scheduling Aspects

A major function of the operating system is to schedule the applications software. It is the design of this area which, above all, formulates the overall traffic characteristics of the system. A poorly designed scheduler results in the inefficient use of the processor utility, either by creating unnecessary overheads or by preventing the processors operating at their optimum occupancy.

Contention Aspects

Whenever demands for a resource are made from multiple sources, contention for the resource may occur. This has the general effect of impairing the efficiency of the system, thereby reducing throughput. In extremely serious cases a poor overload characteristic can result.

In practice, contention can occur from the following causes:

- (a) Processors are wishing to access the same store block simultaneously.
- (b) Communication channels between PEs have messages queuing.
- (c) Queuing exists in accessing the backing store.

Situation (a) is common in closely-coupled multiprocessor systems where code and data reside on common store blocks. Situation (b) is a feature of loosely-coupled systems. Situation (c) is likely to be a problem only with paging machines where excessive paging occurs, but this can be minimized by a suitable storage management philosophy.

Software Optimization Aspects

The traditional approach to software optimization follows 3 simple objectives:

- (a) to make the compiler as efficient as possible,
- (b) to make the code as efficient as possible, and
- (c) to replace time-critical code with assembler.

Quite obviously, such concerns require little teletraffic involvement, but the optimization process must take full account of what is involved in running applications software when live traffic is being carried. There is considerable scope for identifying the most frequently used paths in the software and concentrating on the code in these critical paths. The location of program and data can also play a major role if various levels of storage are used.

However, care must be exercised to ensure that a good throughput is not obtained at the expense of a poor overload characteristic or of a degradation of performance resulting from a change in the traffic character. The software should be

† System Evolution and Standards Department, British Telecom Headquarters

organized so that its run time does not increase with the traffic being handled, and should be designed to run-time objectives that are based on teletraffic requirements.

WORK-LOAD CHARACTERIZATION

The previous section stresses that the final application for the system must be considered throughout every aspect of the design process. Furthermore, if a reasonable understanding of the system's expected behaviour in the practical environment is to be obtained, then it is necessary to understand the nature of the real traffic which will be offered to it. Historically, all systems have been judged or evaluated against a classical traffic model, which was thought to represent practical conditions. However recent studies¹ have clearly demonstrated the need to improve the model used; this is under active study in the British Telecom Teletraffic Division. With processor utilities, which can be designed to operate at high occupancies, the character of call-attempt-rate distributions is of the utmost importance.

Nature of Traffic

Traffic has 3 basic attributes: occupancy (Erlangs), holding time, and calling rate; any subsystem may be sensitive to any 2 of them. Each may have a number of sub-attributes; for example, a call holding time can be broken down into a number of phases, each of which is dependent upon the exact application. Obviously, the Erlang attribute of traffic is of only secondary importance to a processor, whereas the call-attempt rate is paramount. It is therefore necessary to identify a reasonable model for the call-attempt-rate distribution and for the work-load generated by a given call attempt.

Call-Attempt-Rate Model

The British Telecom Teletraffic Division has an ongoing project whose aim is to investigate the long-term behaviour of traffic and, ultimately, to replace the classical traffic model with a more realistic one, which can take due account of within-busy-hour, day-to-day, and seasonal variations. Preliminary analysis of the long-term traffic measurements being made at 2 telephone exchanges (Blackburn and Lincoln), demonstrates quite clearly that the classical traffic model is inadequate and over simplistic¹. Fig. 1 shows an example of the daily call-attempt profile measured at Lincoln telephone exchange and of that recorded during a period of bad weather. In addition, the reliable characterization of newer forms of traffic (for example, Prestel) has yet to be achieved, and cannot be achieved until such traffic is well established.

One major feature of traffic which is ignored in the classical *lost-calls-cleared* model is the phenomenon of repeat attempts. There is overwhelming evidence to show that customers make a significant number of repeat attempts if their calls are unsuccessful, and this fact must not be ignored in the design or dimensioning of call-sensitive equipment. The most important parameters to identify are:

- (a) the perseverance function †,
- (b) the resulting mean number of attempts per call,
- (c) the mean number of attempts given that the first was unsuccessful, and
- (d) the distribution of the time interval between attempts.

With the advent of a *repeat-last-call* facility (which might automatically repeat until successful), these parameters assume great importance. Current evidence suggests a perseverance function of around 0.8–0.9 (which is likely to get higher), and a time-to-repeat measured in tens of seconds (which is likely to get shorter). Thus, if calls are unsuccessful because of congestion in the processor, a repeat is inevitable and could well occur before the congestion has had time to

† The perseverance function is the probability that the customer makes a repeat attempt

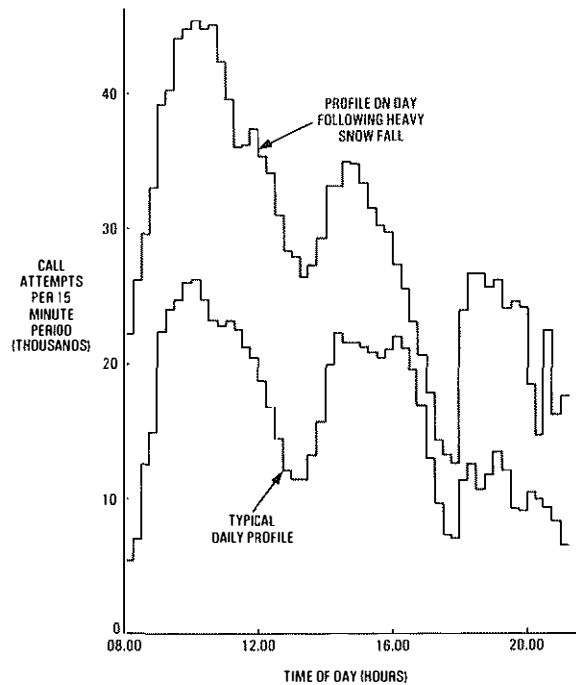


FIG. 1—Call-attempt profile recorded at Lincoln exchange in week commencing 12 Feb. 1979

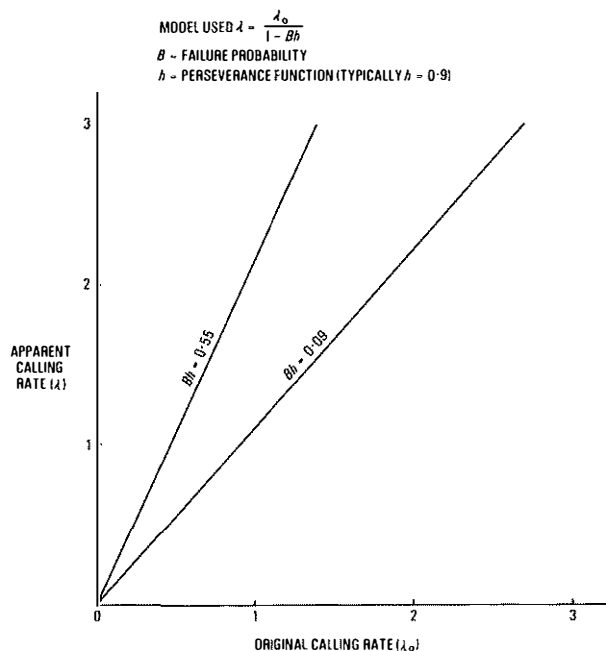


FIG. 2—Effect of customer repeat attempts on the calling rate

pass. Designs must cater for the fact that, under severe overload, an apparent call-attempt rate far in excess of that normally accompanying a given traffic level could be witnessed because of customer repeat attempts. Fig. 2 illustrates this effect under severe conditions.

Load Generated by a Call Attempt

When a call attempt arrives at an exchange, it triggers a sequence of events which causes: messages to be passed between hardware and its handlers; tasks to be passed between processes; processes to be scheduled to run on processors; and storage to be written to and read from. The

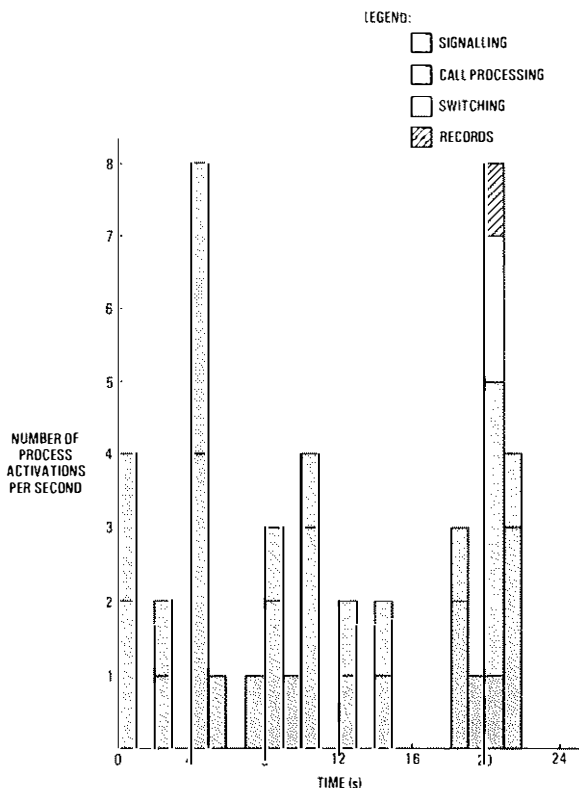


FIG. 3—Typical sequence of demands for processor resources for a decadic-signalled call (for example, SSAC9).

exact sequence of events depends upon the signalling systems being handled, each placing different demands on the processor resources, and in its own time-ordered sequence. Fig. 3 shows a typical sequence of demands for application-program processes involved in establishing a call for a decadic-to-decadic signalled trunk call.

Hence the work-load character, as seen by a processor utility when calls are offered to an exchange from a variety of signalling systems, is perceived as a distribution of demands for processes to be run, as the transmission of messages and tasks, and as the utilization of storage.

Nature of Overloads

The concept of an overload is a subject which has received much attention in recent years, but is still little understood. Such questions as what constitutes an overload, how often do they occur, and with what frequency and duration are often addressed, but very rarely adequately answered. This subsection attempts to identify some characteristics of traffic overloads which ought to receive serious consideration when basic system designs are formulated, as opposed to overloads which can be absorbed by the provision of additional plant.

Types of Overload

Call arrival processes are stochastic; therefore an $x\%$ overload can be practically interpreted as meaning only that the mean call-attempt rate rose by $x\%$ over a defined period of time. Within this defined period, shorter periods exist when the mean call-attempt rate may have been greater or less than the longer-term mean. Reference to standard cumulative Poisson probability tables illustrates the point for classical random traffic. For example, at a mean call-attempt rate of 10 calls/s (36 000 busy-hour call attempts (BHCA)), the probability of 15 or more arriving in 1 s is 8%, and of 30 or

more arriving in a 2 s period is 2%; when these conditions arise, they are not overloads but normal traffic fluctuations.

Sustained increases in demand can be caused by

- (a) unexpected events such as local or national catastrophies,
- (b) predictable events such as "phone-in" programmes,
- (c) late provision of plant,
- (d) forecasting errors,
- (e) tariff changes,
- (f) inaccuracies in dimensioning resulting from the simplistic nature of the traffic model assumed, and
- (g) departures from the traffic model caused by a change in the mean call holding time or calling rate.

In practice, there will also be transient increases in demand which do not last long enough for the system to attain statistical equilibrium and, thus, cannot be measured with any degree of accuracy. The real-time response of a system to such transients can determine the probability of system collapse and should therefore receive extensive study. Unfortunately, such indeterminate situations are difficult to model.

Transient overloads may be caused by equipment failures, sudden cable faults, or as a result of uncontrolled use of automatic alternative routeing (AAR) in the network. They may also coincide with the end of popular TV programmes.

Frequency and Duration of Overloads

Quite surprisingly, there is little factual evidence of the frequency with which overloads occur or of their duration. It can reasonably be conjectured that this is due mainly to the imprecise definition of an overload, coupled with the fact that an event has to last for a significant period of time for it to be measured with any degree of statistical accuracy. It is therefore necessary to improve the traffic model to one which is more representative of the character of traffic. To characterize the imprecise and undefined peaks which could conceivably occur in practice is much more difficult; the only reasonable insurance against them is to ensure that the fundamental subsystem design philosophy is resilient to such surges in demand.

EFFECTS OF THE WORK-LOAD ON SYSTEM BEHAVIOUR

This section discusses in general terms the effects that variations in the offered traffic (the work-load character) have on a practical system. As discussed in the previous section, it is not generally feasible to measure in real time the external stimuli (for example, traffic) to detect an overload, because of the time involved in collecting sufficiently reliable statistics. Therefore, whenever there is an increase in the traffic offered which (momentarily) exceeds the real-time capability of the system, its effect is observed by a change in the behavioural response of the system. Similarly, the load presented to a processor may increase when the traffic (Erlangs or call attempts) appears unaltered. Such a condition can arise from changes in the signalling mix or from some other variation in the traffic's nature, as previously discussed.

Effects of Increasing Demand

The effect from any cause of an increase in demand (or the failure of serving equipment) is observed by increases in queueing times, resulting in increases in system response time. This is obvious, but what is often not fully appreciated is that the queue length and queue-time distributions are normally very short and increase rapidly in the event of only a minor increase in demand. Consider for example, Fig. 4, which gives typical queue lengths and queueing times for a multi-server queueing system with random arrivals and a *first-in-first-out* (FIFO) service discipline. This adequately demon-

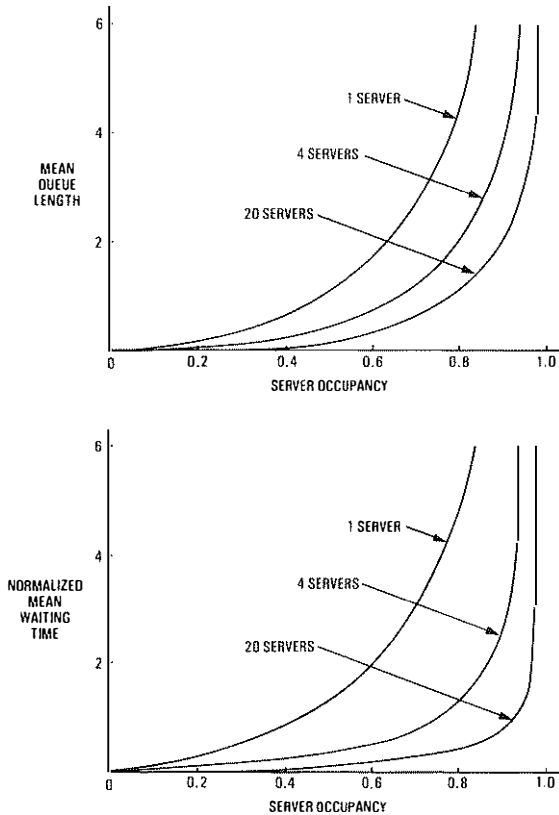


FIG. 4—Multi-server queue curves for random arrivals and a FIFO service discipline

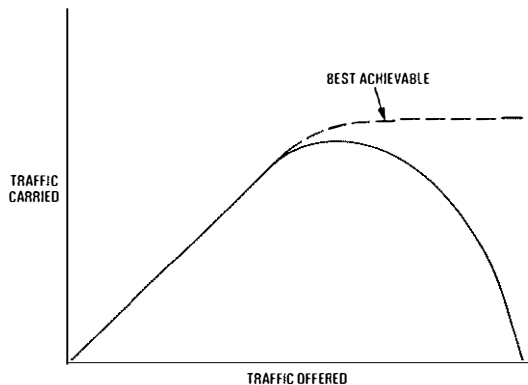


FIG. 5—Typical throughput characteristic when there are no controls present

strates the general picture; as the queueing system becomes more efficient, the knee in the curve becomes more pronounced, resulting in a fast rate of change from a good to a severely degraded performance at high server occupancies.

If queueing times are allowed to increase unchecked, there arises a very serious danger of failure of the signalling-system sequences, which results in lost calls and subsequent repeat attempts. The above discussion of queueing times assumed that service times do not change with increasing demand. This is a complicating factor which should be avoided in the design if at all possible, since the compounded problems could result in throughput seriously falling as demand increases. Typical factors which may cause process-function run times to increase might arise from increased list searching, excessive pre-emption, and blocking of processes awaiting information (for example, delays due to a bottle-neck in obtaining routing translations).

Need for Effective Controls

It is clear from the above discussion that designers must recognize that there is a limit to the calls a processor can handle in a given period of time and that, unless the system philosophy is sound, disorder in, and collapse of, the system may occur when excessive demands are presented. Consequently, the basic system philosophy should contain effective controls that can prevent such undesirable effects occurring. Fig. 5 reproduces the oft-published curve which illustrates a typical throughput characteristic of a closely-coupled processor utility when inadequate controls are provided. An uncontrolled loosely-coupled system could well exhibit an even worse characteristic unless it is adequately optimized for minimum inter-processor communications.

EFFECTIVE LOAD MONITORING

If a processor utility is to be adequately controlled, then its current state has to be properly monitored. Any monitor has to provide unbiased and statistically reliable information, and have a fast response. The controls must know the reliability which they can accord to the monitor information to ensure that any action taken is effective. This reliability must be maximized if a poor overload characteristic is to be avoided. In the design it may well prove worthwhile to consider the trade-offs between maximum throughput and adequate controls. Maximizing throughput may not be the most economic solution if the system exhibits a poor overload characteristic.

Requirements for Load Monitoring

An effective monitor must correctly measure certain system variables to reveal the advent of increases in demand which threaten the system's stability. The main requirements are as follows:

- (a) to be efficient and impose minimum overhead on the processor,
- (b) to have a significant relation with the controlled variables (for feedback purposes),
- (c) to have the ability to identify a momentary peak from a real overload in order to reduce unnecessary intervention,
- (d) to be as fast as possible in its diagnosis, and
- (e) to be able to identify the gravity of an overload so that gradual controls can be applied.

In attempting to interpret these requirements, it is necessary, firstly, to identify which system variables to measure, and secondly, how to measure them. However, it is usually quite difficult to find a parameter whose very short-term values (for example, over a few 100 ms) give an accurate indication of the system state. If the parameter values are averaged over a longer period of time to obtain more reliable results, detection of a sudden onslaught of calls may not be made quickly enough. This apparent impasse in meeting the requirements has led to the idea of using the monitors to prevent overloads rather than to simply detect them. It is important to distinguish between congestion caused by an overload and the overload itself. Prevention of an overload can be carried out only over a relatively long period of time (for example, by backward busying circuits), whereas processor congestion ought to be preventable, even though it would be caused by an overload.

EFFECTIVE LOAD CONTROL

The previous section discussed requirements for load monitoring. The other side of the coin is effective methods of load control.

Requirements for Load Control

The main requirements for designing an automatic load-

control mechanism are as follows:

- (a) It should be as simple as possible.
- (b) The regulation should be restricted to calls causing the overload.
- (c) The effects of congestion should not be allowed to spread through the network.
- (d) The regulation process should not impose a large load on the central control.
- (e) Unaccepted calls should not impose a load on the control.
- (f) Whenever an overload condition disappears, the system should revert immediately to normal working.
- (g) The load controllers should prevent congestion caused by overloads and not simply act after congestion has occurred.
- (h) It should be valid in different applications.
- (i) It should be reliable under all possible circumstances.
- (j) Currently established calls should not normally be affected.

These ideal requirements appear to form an acceptable set, although observance of item (b) may not always give the best solution for the network as a whole, and item (e) may not be practical. In order to enhance the feasibility of meeting these requirements, a good design philosophy must be sought.

Basic Philosophies

The load-control philosophy may be based on open-loop control or closed-loop control principles². Essentially, a closed-loop control method is usually favoured, but care must be taken to ensure that the effects of any controlling action taken, such as rejecting new call demands, are fully under-

stood. The most obvious effect of call rejection is that this action results in an increase in repeat attempts.

In addition, the overall network effects must be considered. For instance, in deciding whether to reject a call, due account should be given to the resources the network has already expended on the call. If AAR facilities exist, the alternative routing of calls caused by backward busying of circuits or routes could spread an overload through the network, unless adequate network controls exist. Finally, if a significant proportion of circuits are permanently backward busied, then the network planners may have to increase the number of circuits provided, in order to maintain route grades of service.

CONCLUSION

This paper has discussed and identified many potential problem areas which could arise in the practical implementation of a processor subsystem, if the teletraffic implications are not considered throughout the design process. There are many topics requiring urgent study, particularly with regard to the application of knowledge gained with closely-coupled systems to a loosely-coupled distributed architecture.

References

- ¹ COLE, A. C., and MACFADYEN, N. W. The Parameterization of All-Day Traffic Profiles. Eighth International Teletraffic Congress, Melbourne, 1976.
- ² HARVEY, C., and GRIFFITHS, P. H. Controlling Overloads in Multiprocessor Systems. Fourth International Conference on Software Engineering for Telecommunications Switching Systems, University of Warwick, July 1981.

Book Reviews

Mathematics for Technician Engineers: A Third-Level Course.
George E. Dyball. McGraw-Hill Book Co. Ltd. xii + 358 pp. 116 ills. £4.95.

This textbook has been written to cover the Technician Education Council's (TEC's) standard unit of Mathematics at Level III. The author has taken the concepts learned at Level II and developed and broadened them so as to prepare a sound basis for further study. The book closely follows the objectives of the standard unit U75/040 and each chapter covers a clearly defined area of the syllabus.

The introductory paragraph of every chapter is a list of objectives that the student should be able to achieve when he has completed his study of that chapter. The text is well laid out and the illustrations are clearly drawn and annotated. Many worked examples are included and all the chapters end with a number of problems, 726 in all, with answers. An interesting point is that the problems have been graded in difficulty by using a system of asterisks.

In chapter 1 the author introduces the concept of mathematical modelling which he develops throughout the book. This is followed by a chapter on trigonometry, covering three-dimensional triangulation, trigonometric functions in terms of frequency and the compound angle formulae. Chapter 3 discusses the binomial theorem, exponentials and napierian logarithms; chapter 4 covers curve fitting and the plotting of log-log and log-linear graphs.

The following 2 chapters deal with differentiation, including second derivatives, turning points, maximum and minimum values and, in a later chapter, first order differential equations. Integration is introduced in chapter 7; in the following 3 chapters it is used to calculate areas, volumes and the first and second moments of areas. There are 3 very good chapters

on probability. In chapter 15 the author brings in the most useful topic of complex numbers, which is additional to the syllabus. Chapter 16 rounds off this excellent book with more work on mathematical modelling and a large number of short and long answer type questions which are used as revision for the whole book.

R. HARVEY

Electrical Drawing. C. B. Firth and J. F. Lowe. McGraw-Hill. viii + 167 pp. 206 ills. Cloth cover: £3.95.

This textbook has been written mainly for Technician Education Council (TEC) students studying electrical and electronic courses. The contents of the book, which covers the learning objectives of the TEC's electrical drawing course, provide useful information and self-assessment questions. This information is presented in a logical sequence, which takes the student from the correct use of instruments to the production of dimensioned drawings. But the book does not explain the basics of orthographic or pictorial drawing in sufficient detail.

Example drawings have been included in the units covering electrical circuits. However, these examples are poorly drawn; they are electrically incorrect and contain errors in the use of line and component symbols. Moreover, the unit on the planning of diagrams teaches the student the expensive, time-wasting method of drawing each individual symbol, without reference to the symbol stencils and guides that are readily available to help the student.

A. C. BALL

Replacement of Incoming Type 8 Register-Translators at Manchester Dalton

J. H. SKELLAND†

The Type 8 electromechanical register-translators (RTs) in the Manchester Dalton incoming trunk unit were first installed in 1961, and the unit has since grown to its present size of 15 translator racks and 9 register groups, totalling 216 registers.

To keep the installation in first-class working order, an ever-increasing amount of maintenance effort has been required. The major part of this effort has been concentrated on the Type 10 relays, which suffer a considerable amount of wear when used in a busy incoming trunk unit such as Manchester Dalton.

With the advancement of the local-exchange modernization programme, surplus Type 13 RT equipment (often referred to as *MOST* directors) became available in the North-West Region. As a result of the successful Edinburgh field trial of using Type 13 RTs in the incoming-register-translator mode, it became obvious that there was scope for using the surplus Type 13 equipment, suitably modified, to improve the incoming STD service to Manchester at a reduced cost. The initial Type 13 RT installation will consist of 2 racks and 168 registers which will replace approximately 80% of the Type 8 installation. Subject to the availability of surplus equipment, full replacement is planned to be completed by mid-1982.

After a visit by area and regional staff to Edinburgh in December 1980, several options were considered for integrating the new Type 13 RT unit into Manchester Dalton. The following method was eventually used.

A pool of 350 register-access relay-sets was modified and tested before the proposed change-over. At a suitably light-traffic period, a group of incoming register-access relay-sets was removed from the racks (and the incoming circuits automatically backward busied), and modified relay-sets substituted. At the same time, a register-hunter group was re-graded to the Type 13 registers. The relay-sets that were made spare were then used as the pool for the next register-group change-over. By using this substitution technique the incoming-circuit routeings were left unaltered, and this avoided costly jumpering and record changes.

The first stage of the new Type 13 RT unit, consisting of 24 registers, was brought into service on 8-9 August 1981. Eventually, the register quantity will be increased to 168 to complete the initial installation. More than 200 test calls were made from the Area Measurement and Analysis Centre through the new incoming Type 13 unit, and the only failure that occurred was in a distant exchange. The in-service performance continues to give every satisfaction and is most encouraging.

Apart from the obvious benefit to STD performance, the use of recovered Type 13 RT equipment to replace Type 8 equipment allows British Telecom to realize the full economic life of the *MOST* equipment.

† Manchester Central Telephone Area

British Telecom Press Notice

WORLD'S LONGEST OPTICAL-FIBRE CABLE

The work of laying the world's longest optical-fibre link—between London and Birmingham—began last autumn. When the link comes into service later this summer, it will form part of Britain's growing optical-fibre network, over which telephone calls, computer data and Telex messages are sent as rapid on-off pulses of light in hair-thin strands of ultra-pure glass.

The new link will be a major achievement in many ways: it will be 125 km longer than any previous British Telecom (BT) optical-fibre link; it will be the first in the UK to operate at long wavelength; it will offer cost reductions, as well as improved reliability, by using light-emitting diodes (LEDs) instead of lasers as light sources; and, although longer links are known to be planned, it is expected to be the longest link in service anywhere in the world when it starts operating.

Britain's optical-fibre network will be the most comprehensive of its kind in the world. Last summer, BT announced plans to buy some 6400 km of optical-fibre cable to augment the 3600 km already on order or being installed. The bulk of this cable will be used to create communications highways in the main network that will carry telephone calls within towns between local exchanges. Optical-fibre links form part of the

country's high-speed digital network being set up under BT's £2000M a year modernization programme.

The London-Birmingham optical-fibre cable, which is being manufactured by BICC Telecommunication Cables Ltd., will contain 8 fibres, each 125 μm in diameter. Plessey Telecommunications Ltd. will supply the associated electronic transmission equipment; this will use high-radiance LEDs emitting at a wavelength of 1.3 μm as compared with 0.85-0.90 in earlier systems. The longer wavelength radiation travels further in the optical fibre (its attenuation is less than 1.5 dB/km) and allows the intermediate regenerators to be installed up to 25% further apart than on existing optical-fibre systems. Initially, 2 optical-fibre pairs in the cable will be brought into service. These will operate at 34 Mbit/s, each able to carry up to 480 telephone calls simultaneously. In 1983, the other 2 pairs will be used for 140 Mbit/s operation, each with a capacity of 1920 calls.

The new optical links ordered for the junction network range in length from 1.5 km to 40 km. They comprise 22 routes operating at 34 Mbit/s, and are able to carry 480 telephone calls simultaneously, and 15 routes at 8 Mbit/s with a capacity for 120 calls each. Nine of the 34 Mbit/s routes will be in London. All the junction systems will be brought into service during 1983-84.

Changing the PMBX1A for a PMBX11A at County Hall, Truro

D. K. A. CHATTERTON and G. D. BROWN†

In 1979, Cornwall County Council decided that the telephone installation at County Hall, Truro, was no longer adequate to meet the needs of the county's administrative authority. Their system at that time, a PMBX1A with 5 positions, 40 exchange lines, and 360 extensions, had been installed when the building was completed in 1966. There followed lengthy discussions with various telephone contractors about the possibility of installing a modern stored-program control (SPC) type exchange, but it was decided that, because of financial restrictions, a more modest installation should be considered. British Telecom (BT) was approached, and the Sales Division at Truro negotiated the supply of a PMBX11A with 8 positions. At the same time, consultations took place between the customer and the planning officer of the Truro Customer Works Group (CWG). There were 2 major problems to be overcome: the lack of accommodation, and the avoidance of any interruption of service.

The accommodation for the PMBX1A consisted of the apparatus room (23 m²) and the switchboard room (35 m²). Although the switchboard room could accommodate the new PMBX11A switchboard, it could only do so with the PMBX1A switchboard removed. The cost of adding a purpose built extension for the new switchboard would have been considerable, and there was no other spare space in the building. The customer was very concerned that there should be no break in telephone service; the question was whether the PMBX1A could be moved to a temporary site during the change-over, while it was still working.

Because the County Hall is on a sloping site, the switchboard room is almost like a cellar under part of the main building. A wide driveway forms part of its roof, and its doors and windows face onto a lower car park (see Fig. 1).

The idea was conceived of moving the switchboard out from its room into a temporary building, such as a *Portakabin*, and then positioning the *Portakabin* where it was easily accessible. The CWG was able to work out a scheme for transferring the PMBX1A switchboard from the switchboard room into a *Portakabin* and then hoisting the *Portakabin*

into a position on the driveway above the room. In this way, service would not be interrupted.

The customer held discussions with the switchboard staff regarding working conditions, and checked the loading factors for the proposed site.

The switchboard had to be transferred as a complete unit and, to this end, it was decided to extend each cable from the apparatus room to the switchboard. This was achieved by using a modular jointing machine, and about 2000 wires were involved.

The outside wall of the switchboard room had 2 windows, the frames of which were the full height of the room. One window was directly in line with the switchboard suite, and the window opening allowed a clearance of 80 mm on the maximum width of the suite. The window was not glazed to the floor level and there were central heating pipes passing across it, but these were easily surmountable difficulties. The entrance to the switchboard room from the apparatus room was by a door adjacent to the window, and this made it possible for cable to be run through a removable panel over the door, out at high level through the window, up the granite face of the building, and into the *Portakabin* on the driveway above. This would enable a completely clear working area to be established for the installation of the new suite.

The switchboard, which weighed about 500 kg, had to be moved quickly and easily. It was decided that the safest solution was to fit castors to the switchboard. A metal frame was constructed from 75 mm × 75 mm L-section mild steel; it ran the full 6 m length of the suite, had bolted-on side pieces, and was supported by 10 castors (see Fig. 2). The main virtue of the design was the ease with which, by tilting the front and rear in turn, it could be assembled without the need to use heavy lifting gear within the confines of the switchboard room. A check of the area outside the proposed window/door-

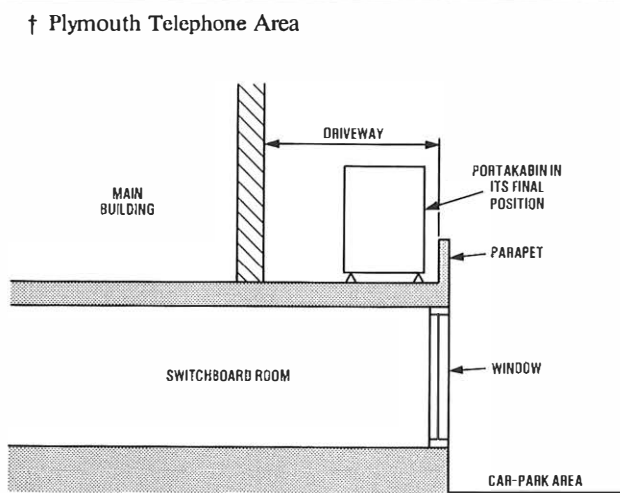


FIG. 1—Side elevation of the site



FIG. 2—The PMBX1A switchboard suite with its supporting frame

way exit revealed that a Portakabin could be manoeuvred up to the entrance even though the ground level was about 660 mm below the switchboard-room floor.

Portakabin Ltd. supplied a unit with end doors opening outwards and a section at the bottom of one door constructed so as to allow the passage of telephony cables. They also ensured that the floor would take the weight of the switchboard and the staff. Cornwall County Council agreed to remove the window, heating pipes and panel above the door, and to reinstate them after completion of the work.

The Portakabin was delivered to the site on Friday, 3 April 1981, and on the following day at 08.00 hours a crane, supplied by the Council, started lifting the Portakabin to a position adjacent to the enlarged window gap. Once the Portakabin was in position the PMBX1A switchboard was moved into it. The complete installation was then ready to be hoisted onto the new site on the driveway immediately above the old switchboard room (see Fig. 3). The operation took place without any serious problems despite the obvious strain on the castors used. By mid-morning the Portakabin was in place and the switchboard fully operational with no faults having occurred.

The PMBX11A switchboard was fitted into the completely clear space left by the removed PMBX1A suite, but the apparatus room became rather congested. Fortunately, it was possible to increase space by turning one existing apparatus rack and moving the existing battery and rectifiers to accommodate the main distribution frame (MDF), relay sets, and ancillary equipment for the new PMBX. The necessary cabling of the County Hall had to take place before the wiring of the new suite was complete, the entire installation involving some 62 000 terminations.



FIG. 3—The Portakabin being hoisted into position

The job was a challenge, but the customer's needs have been met in all respects. While the provision of a PMBX11A does not conform to the current trend towards SPC PBXs, it is, nevertheless, a considerable improvement, both visually and operationally, on the PMBX1A. The service given by the County Hall operators has been improved, and Cornwall County Council has saved ratepayers an estimated £4M.

Book Review

Introduction to Adaptive Arrays. Robert A. Monzingo and Thomas W. Miller. John Wiley & Sons Ltd. xii + 543 pp. 184 ills. £19.15.

Adaptive antenna arrays are of intense interest today, and this book is an excellent introduction to the fundamental design of such systems and to their application for the reduction of interference, removal of jamming and in creating retro-directive properties (that is, directing transmitted energy in the direction of a received signal). What is being dealt with is a relatively new technology, born of today's ability to carry out complicated and intense signal processing in the control area. But the technology has a long and respectable history; beginning with the early use of direction finding arrays of various forms, the arrays were soon employed, albeit with manual control, to reduce interfering signals as well as to determine arrival bearings. Indeed, many designs of multi-element steerable arrays have sprung from direction finding, and these arrays, under the pressure of interference and, perhaps most of all, electronic warfare, are now yielding systems of almost unbelievable performance, particularly in speed of response.

This book has been written by 2 practitioners of this art,

rather than by abstract researchers, but it obviously owes much to close academic contacts. It begins with an excellent tutorial section, dealing with basics, uses and systems, and then moves on to a comprehensive study of adaptive algorithms, the erstwhile intelligent machines which have much in common with pattern recognition, control theory, adaptive equalization and other areas of modern signal processing. However, practical applications are not forgotten among the welter of alternatives, and in most cases leads are given to applications and to relative evaluations.

A final section brings the subject up-to-date with modern research trends, notably partially-adaptive arrays which are aimed at reducing the number of control elements without significant loss of performance.

Two of the most attractive facets of this lengthy book are the inclusion of worked examples to aid the practising designer, and the very excellent bibliographies at the end of each chapter.

Although this is a specialist's book which will appeal to the antenna designer and the signal processor, it will also appeal to anyone interested in adaptive systems.

S. G. YOUNG

Institution of Post Office Electrical Engineers

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(Membership and other local enquiries should be directed to the appropriate Local-Centre Secretary as listed in the October 1981 issue)

AMENDMENT TO THE RULES OF THE INSTITUTION ON INCREASED SUBSCRIPTION

A proposed amendment to Rule 13 was submitted by Council to the Membership in accordance with Rule 33 and, there being no objections, Rule 13 should be amended to read as follows:

“Subscriptions. The annual subscription to the Institution shall be as follows:

Corporate Members:	
Member	£3.96
Affiliated Member	£3.96
Non-Corporate Members:	
Corresponding Member	£4.00

Members who retire from the Post Office and who retain their membership may commute their annual subscriptions by payment of the sum of £3.50.”

The increase was introduced on 1 October 1981. Members are reminded that income-tax relief can be claimed on their subscriptions, by quoting reference CI/SUB/459 dated 2 March 1959.

THE NEW TITLE OF THE INSTITUTION

The result of the ballot of Members on the new title of the Institution was as follows:

Institution of British Telecommunications and Post Office Engineers (IBTPOE)	777
Institution of British Telecommunications Engineers (IBTE)	6542
Spoiled papers	6
Total	7325

Of the total Membership, 55% took part in the ballot. (This represents 57% of those eligible to vote.)

The new title, *The Institution of British Telecommunications Engineers*, will be introduced on 1 April 1982.

CIRCULATION OF PERIODICALS

Council agreed at its meeting on 18th November 1981 to withdraw the right of retired members to receive a periodical on circulation, because of the high cost of postage involved. Council extends its apologies to the few retired members affected and trusts that the necessity for this decision will be appreciated.

R. E. FARR
Secretary

IPOEE CENTRAL LIBRARY

The books listed below have been added to the IPOEE library since the latest catalogue supplement was issued. Any member who does not have a copy of the catalogue can obtain one on loan from The Librarian, IPOEE, 2-12 Gresham Street, London EC2V 7AG. Library requisition forms are available from the Librarian, from Local-Centre and Associate Section Centre secretaries and representatives. The form should be sent to the Librarian. A self-addressed label must be enclosed.

5336 *A Bit of Basic*. T. A. Dwyer and M. Critchfield (1980).

This book provides an informal but thorough introduction to computer programming in BASIC.

5337 *Principles of Programming: An Introduction with Fortran*. E. B. Jones (1980).

This book outlines how computers work and describes the significant features of the FORTRAN programming language.

5338 *Electrical Energy: Its Generation, Transmission and Use*. E. R. Laithwaite and L. L. Freris (1980).

The authors discuss the problems of power engineers and attempt to answer a range of questions on the subject of power systems; both old and new systems are explored.

5339 *Electrical Circuits and Systems*, second edition, N. M. Morris (1980).

In this book test questions and worked examples are used to help provide a useful understanding of the subject.

5340 *The Microelectronics Revolution*. T. Forester (1980).

The silicon-chip revolution is comprehensively explored, with contributions from experts in several fields on the social and technological implications of the micro-chip industry.

5341 *Computing Science*. D. C. Palmer and B. D. Morris (1980).

This book is an introduction to computing. The major problem-solving techniques are discussed and examples of the mathematical background of computing are provided.

5342 *The First 100 Years of Telephones Viewed from Norwich*. E. Clayton (1980).

This interesting book charts the progress made in telecommunications in the Norwich Telephone Area over the past 100 years.

P. C. LYALL
Librarian

Notes and Comments

CONTRIBUTIONS TO THE JOURNAL

Contributions to the *POEEJ* are always welcome. In particular, the Board of Editors would like to reaffirm its desire to continue to receive contributions from Regions and Areas, and from those Headquarters departments that are traditionally modest about their work.

Anyone who feels that he or she could contribute an article (short or long) of technical, managerial or general interest to engineers in British Telecom and the Post Office is invited to contact the Managing Editor at the address given below. The editors will always be pleased to give advice and try to arrange for help with the preparation of an article, if needed.

GUIDANCE FOR AUTHORS

Some guiding notes are available to authors to help them prepare manuscripts of *Journal* articles in a way that will assist in securing uniformity of presentation, simplify the work of the *Journal's* editors, printer and illustrators, and help ensure that authors' wishes are easily interpreted. Any author preparing an article is invited to write to the Managing Editor, at the address given below, to obtain a copy.

All contributions to the *Journal* must be typed, with double spacing between lines, on one side only of each sheet of paper.

As a guide, there are about 750 words to a page, allowing for illustrations, and the average length of an article is about 6 pages, although shorter articles are welcome. Contributions should preferably be illustrated by photographs, diagrams or sketches. Each circuit diagram or sketch should be drawn on a separate sheet of paper; neat sketches are all that is required. Photographs should be clear and sharply focused. Prints should preferably be glossy and should be unmounted, any notes or captions being written on a separate sheet of paper. Good colour prints and slides can be accepted for black-and-white reproduction. Negatives are not required.

It is important that approval for publication is given at organizational level 5 (that is, at General Manager/Regional Controller/BTHQ Head of Division level) and authors should seek approval, through supervising officers if appropriate, before submitting manuscripts.

Contributions should be sent to the Managing Editor, *The Post Office Electrical Engineers' Journal*, NEP 12, Room 704, Lutyns House, Finsbury Circus, London EC2M 7LY.

SPECIAL ISSUES AND BACK NUMBERS

Copies of the April 1974 issue covering sector switching centres; the October 1973 special issue on the 60 MHz transmission system; and the October 1981, IPOEE 75th Anniversary special issue are still available.

Back numbers can be purchased, price £1.30 each (including postage and packaging), for all issues from April 1974 to date, with the exception of April and October 1975 and April 1976. Copies of the April 1973 issue are also still available.

Orders, by post only, should be addressed to *The Post Office Electrical Engineers' Journal* (Sales), 2-12 Gresham Street, London EC2V 7AG. Cheques and postal orders payable to "The POEE Journal", should be crossed "& Co." and enclosed with the order. Cash should not be sent through the post. A self-addressed label accompanying the order is helpful.

MAC REPRINTS

The articles on *Measurement and Analysis Centres (MACs)* published in previous issues of this *Journal* have been com-

bined, with minor amendments, and reprinted as a single booklet, and this is now freely available on request. To obtain copies of this booklet send a self-addressed A4-sized envelope to: BTHQ ES5.0.2., Tenter House, 45 Moorfields, London EC2Y 9TH. The bottom left-hand corner of the envelope should be marked MAC (), and the number of copies required inserted inside the brackets; for example, MAC (2). Although no charge is being made for these reprints, non-employees of British Telecom are requested to stamp the self-addressed envelopes at the appropriate postal rate (net weight per copy is 125g).

SYSTEM X REPRINTS

The 26 articles on System X that appeared in the *Journal* between January 1979 and April 1981 have been reprinted into a single 160-page book. Further details and an order form are printed on page 377 of this issue of the *Journal*.

REVISED LIBRARY CATALOGUE

A revised library catalogue will be available from 1 April 1982, the date on which the new title of the Institution is introduced.

CORRECTION

In the article *The Evolution of the Inland Telecommunications Network* published in the October 1981 issue of the *POEEJ*, Fig. 7 on p. 164, which shows the 1960 Transmission Plan, contains some errors. In particular certain loss figures have been amended, and some loss figures have been prefixed to indicate that they are limiting losses. A corrected version of the illustration is reproduced below.

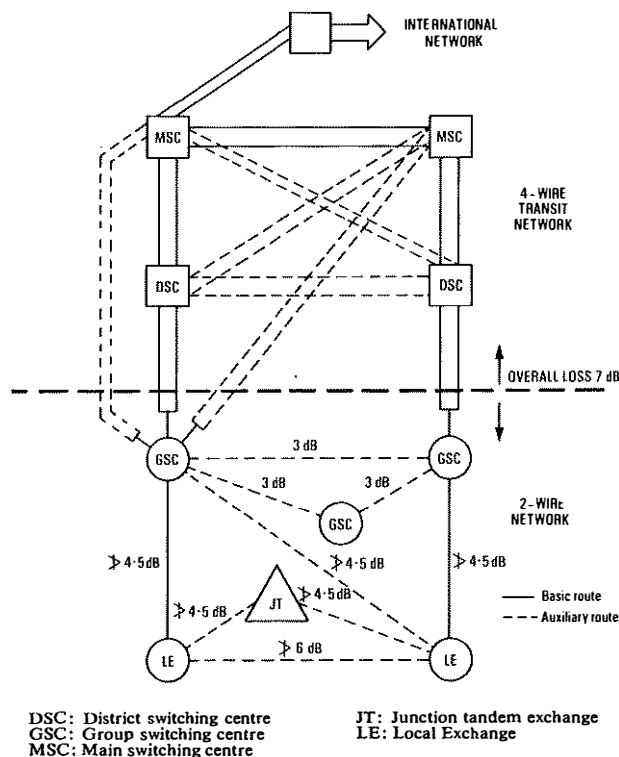


FIG. 7-1960 Transmission Plan

Forthcoming Conferences

Further details can be obtained from the conference department of the organizing body.

FORUM 83 Secretariat, International Telecommunication Union, CH-1211 Genève 20, Switzerland. Telephone: +41-22-995190

FORUM 83: Fourth World Telecommunications Forum, Part 2, Technical Symposium

29 October–1 November 1983

New Exhibition and Conference Centre, Geneva

Call for Papers: Papers are invited that comprise of original unpublished work dealing with subjects in the technical areas listed below. The deadline for summaries is 1 November 1982 (further details from the FORUM 83 Secretariat).

Technical Areas: Technology trends and design impact, telecommunication networks evolution, telecommunication services today and tomorrow, user terminal equipment, terrestrial and space telecommunication systems, telecommunications in developing areas and radio-frequency spectrum and management.

Institution of Electronic and Radio Engineers, 99 Gower Street, London, WC1E 6AZ. Telephone: 01-388 3071

International Conference on Fibre Optics

1–2 March 1982

Institute of Marine Engineers, London

Video and Data Recording

20–23 April 1982

University of Southampton

The Influence of Microelectronics on Measurements, Instruments and Transducer Design

29 June–1 July 1982

University of Manchester, Institute of Science and Technology

International Conference on Electromagnetic Compatibility

21–23 September 1982

University of Surrey

Institution of Electrical Engineers, Savoy Place, London WC2R 0BL. Telephone: 01-240 1871

HF Communication Systems and Techniques

15–16 February 1982

Institution of Electrical Engineers

Communications 82: Communications Equipment and Systems

20–22 April 1982

Birmingham Metropole Hotel, National Exhibition Centre, Birmingham

International Conference on Man/Machine Systems

6–9 July 1982

University of Manchester, Institute of Science and Technology

1982 International Symposium on Subscriber Loops and Services (ISSLS 82)

20–24 September 1982

The Toronto Hilton Harbour Castle Convention Centre, Toronto, Canada

Secretariat 83 International Zurich Seminar, Miss M. Frey, EAE, Siemens-Albis AG, CH-8047 Zurich, Switzerland. Telephone: +41-1-4955120

1982 International Zurich Seminar on Digital Communications: Man-Machine Interaction

9–11 March 1982

Swiss Federal Institute of Technology

DIEU Danish Engineers' Post Graduate Institute, The Technical University of Denmark, bldg. 208, DK-2800 Lyngby, Denmark. Telephone: +45-2-882300

Reliability in Electrical and Electronic Components and Systems

14–18 June 1982

The Technical University of Denmark

Profiles of Senior Staff

DIRECTOR: EXCHANGE SYSTEMS

J. TIPPLER

John Tippler joined British Telecommunications (BT) in 1947 as a Youth-in-Training at Spalding in the Peterborough Telephone Area. After a variety of mainly maintenance duties and a spell in the Royal Signals, he transferred to the (then) Central Training School, Stone, in 1954. Amongst other things, he was a member of the small team that established the earliest electronic switching courses



in the late-1950s.

In 1959 he moved to the Telephone Development Branch of the Engineer-in-Chief's Office to work on the development of register translators; in 1962 he joined the Electronic Exchange Development Branch which had been set up under J. A. (Johnny) Lawrence. Here, he was principally concerned with reed-electronic exchange developments which culminated in the initial main production phase of TXE4, for which he headed BT's development team.

Prior to his appointment as a Director, he was Head of Division and the Deputy Director of the System X Development Department, responsible for the design aspects of the overall system.

He is married and has 2 sons; his leisure activities include music and motor cycling.

DIRECTOR: OVERSEAS LIAISON AND CONSULTANCY

J. F. BOAG, DIP.E.E., C.ENG.,
M.I.E.E., F.B.I.M.



John Boag joined the British Post Office in 1944 as a Youth-in-Training at Aberdeen. After service in the REME, he returned to repeater station maintenance in Aberdeen; this was followed by service as a demonstrator at the Regional Training School, Edinburgh, and, after promotion to Assistant Executive Engineer, on repeater station construction work at the TATI terminal, Oban.

He moved to Telecommunications Headquarters in 1958 as an Executive Engineer engaged on systems engineering work connected with the US—Bermuda and COMPAC submarine cable systems; he was promoted to Senior Executive Engineer in 1965. During 1967–68 he was seconded to COMSAT, in Washington DC, where his systems engineering experience was put to good use on various INTELSAT satellite systems.

Returning to the UK, he was promoted to Assistant Staff Engineer with responsibility for microwave radio-relay construction and then for network planning, a task which he continued as a Head of Division. It was during this period that the plans for the future digital trunk transmission network were formulated.

His association with consultancy work started in 1975 and this work eventually led to the creation of British Telconsult in 1979 and to his appointment as General Manager of the new organization. Under his guidance consultancy work grew rapidly into a multi-million-pound business.

His appointment as Director of the Overseas Liaison and Consultancy Department has brought his attention to the wider issues that affect the success of British telecommunications equipment in the export market.

DIRECTOR: ENERGY, TRANSPORT AND ACCOMMODATION

D. N. DICK, C.ENG., F.I.MAR.E.,
M.R.I.N.A.



Douglas Dick was born in Newcastle-upon-Tyne and educated at the County Technical School, Romford, Essex. Before joining British Telecommunications (BT) in 1955 as a junior marine engineer, he served a marine-engineering apprenticeship with William Denny Brothers, Dunbartonshire, and worked for the Union Castle Steamship Company.

In 1966 he was promoted from Chief Engineer to Assistant Superintendent Marine Engineer. A year later he was promoted to Superintendent Marine Engineer with responsibility for the maintenance of BT's cable ships; he also took charge of the design and construction of the cable ships, *Monarch* and *Iris*.

In 1978, he became head of the Marine Division, with overall responsibility for the laying and repairing of submarine cable systems for both BT and other administrations.

As Director: Energy, Transport and Accommodation, he is responsible for the development of power-supply systems and stand-by generators for telephone exchanges and other buildings; for building services and plant development, which includes heating, ventilation and air conditioning; for motor transport, which ranges from saloon cars and vans to articulated lorries; and for building standards and policies.

He is married, has 3 children—a daughter and 2 sons—and lives at Ashley Heath, Ringwood, near Bournemouth. His hobbies include gardening and building radio-controlled models.

British Telecom Press Notice

BRITISH TELECOM INTRODUCES CARGO SYSTEM AT HEATHROW AND GATWICK AIRPORTS

A major new computer-controlled data system covering both exports and imports has been successfully brought into service by British Telecom (BT).

The system is at present in operation at Heathrow and Gatwick airports, where it controls the movement of about 30% of the nation's overseas trade. It works round the clock every day of the year to streamline the clearance of imports through customs and to speed the despatch of exports. It enables users to keep track of consignments from their own premises at a lower cost than the earlier import-only system that it has replaced.

The system, known as *air cargo processing in the 80s* (ACP80), is operated for nearly 350 participating organizations—38 airlines and transit-shed operators, 300 freight-forwarding agents and Customs-and-Excise—by the National Data Processing Service (NDPS), BT's commercial computing

arm, which was awarded the contract in 1979.

The scheme is run on computers at BT's Harmondsworth computer centre, located just west of Heathrow airport. ACP80 is one of the most technically advanced systems in the world and uses BT's new packet-switched data service (PSS) to carry cargo information between the ACP80 computers and the separate computer systems operated by 6 major world airlines. Customs, agents and the 32 airlines served by the bureau access the ACP80 computers through terminals in their offices. These are visual display units and high-speed teleprinters that reproduce computer information on paper.

ACP80 has replaced the highly successful London Airport cargo electronic data-processing scheme (LACES) which was run by NDPS and which was another first of its kind when it was put into operation in 1971 to handle the clearance of imports at Heathrow airport. Smaller than ACP80, LACES served the customs authority, some 20 airlines and 60 agents with visual display units in offices within the airport boundaries. ACP80 is able to include agents having offices anywhere in the UK, and covers exports.

Book Reviews

Diffraction Theory and Antennas. R. H. Clarke and John Brown. John Wiley & Sons Ltd. 222 pp. 121 ills. £25·00.

As would be expected from the provenance of these authors, this is an excellent book that makes a valuable contribution to the training of undergraduates in antenna design principles; at the same time it is an excellent refresher text for working engineers. Naturally, within the terms of its title the book has nothing to say on arrays, halfwave dipoles, mutual impedances and so forth, but concentrates on what have come to be known as *aperture antennae*. It sets about introducing an air of engineering practice from the outset. By page 17 particular antennae have been described and the scene set for a basic discussion of directivity, gain and aperture efficiency. There follows a very effective exposition of the angular spectrum concept, which is then used to study the antenna as a transmitter and receiver. After further chapters on diffraction, in the Fresnel region, and on reflection, the student is introduced to the application of his studies to antenna design.

Throughout the book there are examples, or rather exercises, to be worked, often with hints about the method of solution. If there is a point of criticism, it is that these exercises, while aiding understanding, do not extend the student to the simplest synthesis of design, although it must be admitted that they do introduce him to important factors such as sidelobe levels.

Finally, 2 appendices at the end of the book contain a development of waveguide theory from transmission line theory, a summary approach to Maxwell's equation and some of its consequences.

In all, this is a book which can be recommended to the student and to the designer, both as support to a course and as a fundamental yet practical reference book.

S. G. YOUNG

Interference Analysis of Communications Systems. Edited by Peter Stavroulakis. John Wiley & Sons Ltd. viii + 424 pp. 305 ills. £17·50.

This volume, which is in the IEEE selected reprint series, covers a wide interpretation of interference; for the selected articles (some 60% from IEEE Transactions) include such subjects as multipath and echo interference, and fading effects. A section is devoted to interference reduction, by adaptive antennae or cancellation systems, and by the reduction of sidelobe levels.

Many of these articles will be well known to system designers and planners. The advantages of this collection is that it not only presents a selected collection in a handy form, but also a wider picture than most personal collections. Perhaps one might argue about the particular selections, but all the articles include an extensive bibliography, and many are not purely theoretical but include some experimental results. What is missing, however, is the practical knowledge needed to apply many of these results to practical, and imperfect, systems that are often open simultaneously to many of the factors that are discussed only in isolation in the book. In short, although providing tools, the book does not tell the reader how to use them, and it is to be regretted that no general articles on frequency planning are included; for after all, interference studies are most relevant to the efficient allocation of the spectrum.

This book will be of great use to the system engineer and to system engineers in industry working in organization and administration. This is a book to have by one, as a source and constant reference rather than as a textbook. It forms a sound foundation for newcomers to the field, but is in no sense a text book; it is a selection of specialized professional articles with a bias towards wide-band high-quality communications.

S. G. YOUNG

British Telecom Press Notice

WORLD-WIDE VIEWDATA CONNEXION IMMINENT

After the announcement by European and other countries of a series of agreements last autumn, a world-wide viewdata service is rapidly becoming a reality. At *Viewdata 81*, held at Wembley last October, Richard Hooper, Director of Prestel, announced at the plenary conference session that a number of European countries proposed to take the initial steps towards the interconnexion of their national viewdata systems in 1982-83.

After its success in West Germany, the gateway facility, which allows viewdata customers easy access to a wide range of existing, non-viewdata computers, is to be implemented in the Netherlands and Italy, as well as in the UK. Austria and Hong Kong are considering the introduction of the facility, and France is already evaluating it in Vélizy, near Paris.

In addition to allowing the connexion of non-viewdata computer systems, the introduction of the gateway facility

will result in the interconnexion of national viewdata systems. This means, for example, that a Prestel user in the UK will be able to access the *Bildschirmtext* service in Germany, and vice versa. This interworking provides further evidence of the close relationships that have been established in the European viewdata community since a European viewdata standard was agreed by the European Conference on Posts and Telecommunications (CEPT) in May 1981.

The imminent interconnexion of national viewdata systems means that overseas viewdata operators will gather users for the international viewdata system, of which Prestel is a major element.

Prestel will continue to give widespread overseas access to foreign users; but, as national systems develop and interlink, direct access to Prestel computers in the UK will be gradually replaced by access via national gateways.

Prestel continues to sell its systems overseas, and at present 7 countries have purchased Prestel's viewdata technology. Enhancements to the systems already purchased by Italy and Austria were announced at *Viewdata 81*.

The Post Office Electrical Engineers' Journal

REPRINTS OF

System X

ARTICLES

The Post Office Electrical Engineers' Journal is reprinting, as a single 160-page book, the 26 articles on System X which appeared in the *Journal* between January 1979 and April 1981. The articles in this book describe:

- (a) The concepts of System X and its use in the UK telecommunications network.
- (b) The principles of the system, including aspects related to digital switching, common-channel signalling, and processor control.
- (c) The individual subsystems.
- (d) The hardware and software.
- (e) The design and support of modern switching systems.

The articles were written over a period of 3 years whilst the initial stages of development of System X were proceeding. As a result of advances in technology since the start of development, many significant changes have taken place within the subsystem designs. Specifically, the processor subsystem has been revised to take advantage of new technology, whilst still retaining a multi-processor form. The one processor architecture is used throughout the system family. The overall system concepts and the network applications still remain as described in the articles.

The cost of this book is £3.00 including post and packaging (the cost to British Telecom (BT) and British Post Office (BPO) staff is £1.20).

If you wish to order copies of this book, please complete the appropriate section of the order form below and send it to the address shown. (Cheques and postal orders, payable to "The POEE Journal", should be crossed "& Co." and enclosed with the order. Cash should not be sent through the post.)

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Please supply 4 quarterly issues of *The Post Office Electrical Engineers' Journal*. I enclose a cheque/postal order for the sum of £5.20 (Canada and the USA: \$12) to cover the yearly subscription.

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Please state with which issue you wish your subscription to commence (April, July, October or January).....

The Post Office Electrical Engineers' Journal

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The Board of Editors is not responsible for the statements made nor the opinions expressed in any of the articles or correspondence in this *Journal*, unless any such statement is made specifically by the Board.

Subscriptions and Back Numbers

The *Journal* is published quarterly in April, July, October and January, at 80p per copy (£1.30 per copy including postage and packaging); annual subscription: £5.20; Canada and the USA: \$12.00.

The price to British Telecom and British Post Office staff is 48p per copy.

Back numbers will be supplied if available, price 80p (£1.30 including postage and packaging). At present, copies are available of all issues from April 1974 to date with the exception of the April and October 1975 and April 1976 issues.

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Employees of British Telecom and the British Post Office can obtain the *Journal* through local agents.

Binding

Readers can have their copies bound at a cost of £7.50, including return postage, by sending the complete set of parts, with a remittance, to Press Binders Ltd., 4 Iliffe Yard, London SE17 3QA.

Remittances

Remittances for all items (except binding) should be made payable to "*The POEE Journal*" and should be crossed "& Co."

Distribution and Sales

Correspondence relating to the distribution and sale of the *Journal* should be addressed to *The Post Office Electrical Engineers' Journal* (Sales), 2-12 Gresham Street, London EC2V 7AG.

Communications

With the exceptions indicated all communications should be addressed to the Editorial Office, *The Post Office Electrical Engineers' Journal*, NEP12, Room 704, Lutyens House, Finsbury Circus, London EC2M 7LY (Telephone: 01-357 4313).

Advertisements

All enquiries relating to advertisement space reservations should be addressed to Mr. N. G. Crump, The Advertisement Manager, *Post Office Electrical Engineers' Journal*, Room 508, 2-12 Gresham Street, London EC2V 7AG (Telephone: 01-357 2089).

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. Copies of the syllabi and question papers are not sold by *The Post Office Electrical Engineers' Journal*, but may be purchased from the Sales Department, City and Guilds of London Institute, 76 Portland Place, London W1N 4AA.

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INDEX TO ADVERTISERS

Advertisements

Communications should be addressed to Mr. N. G. Crump, The Advertisement Manager, *POEEJ*, Room 508, 2-12 Gresham Street, London, EC2V 7AG (Tel: 01-357 2089).

No responsibility is accepted by the Journal for any of the private or trade advertisements included in this publication.

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BICC-VERO Connectors, Ltd.	4
British Telconsult	2
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Alternatively, the panel below, or a photocopy, can be used (only by members) to borrow any book listed in the catalogue or in the updating lists published in recent issues of the *POEEJ*. The form should be sent to the Librarian at the address above; a self-addressed label must be enclosed.

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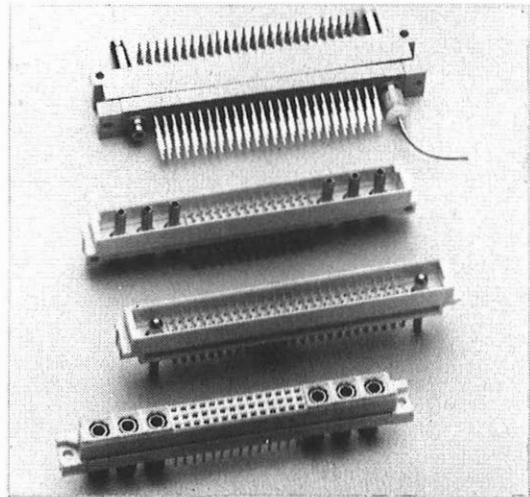
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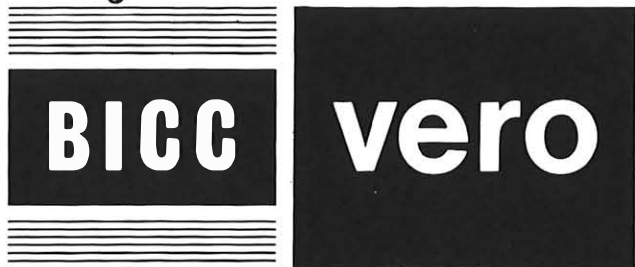
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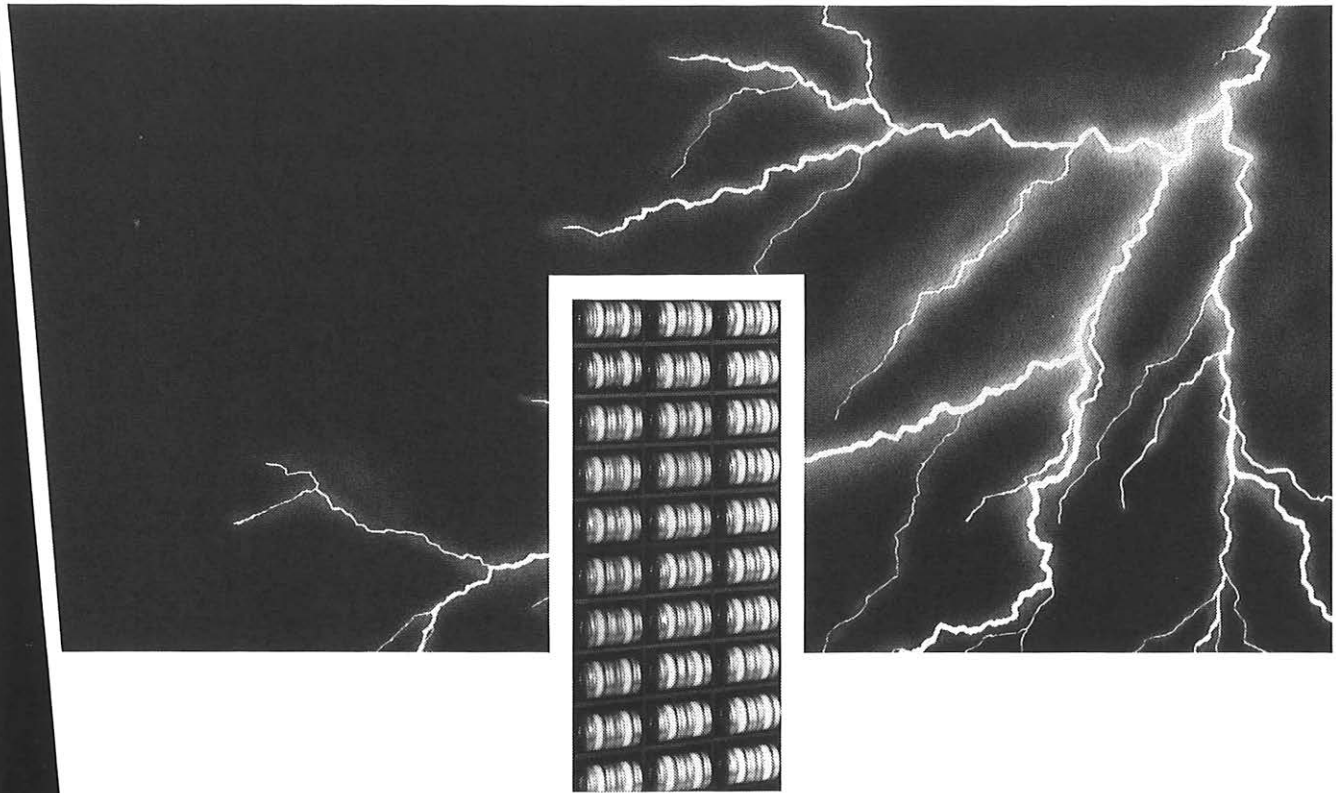
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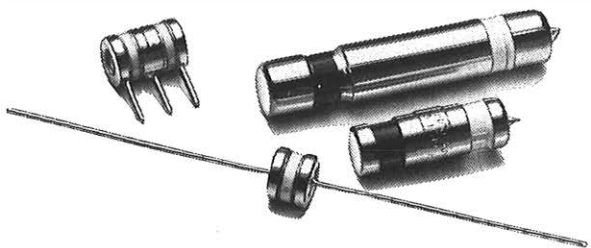
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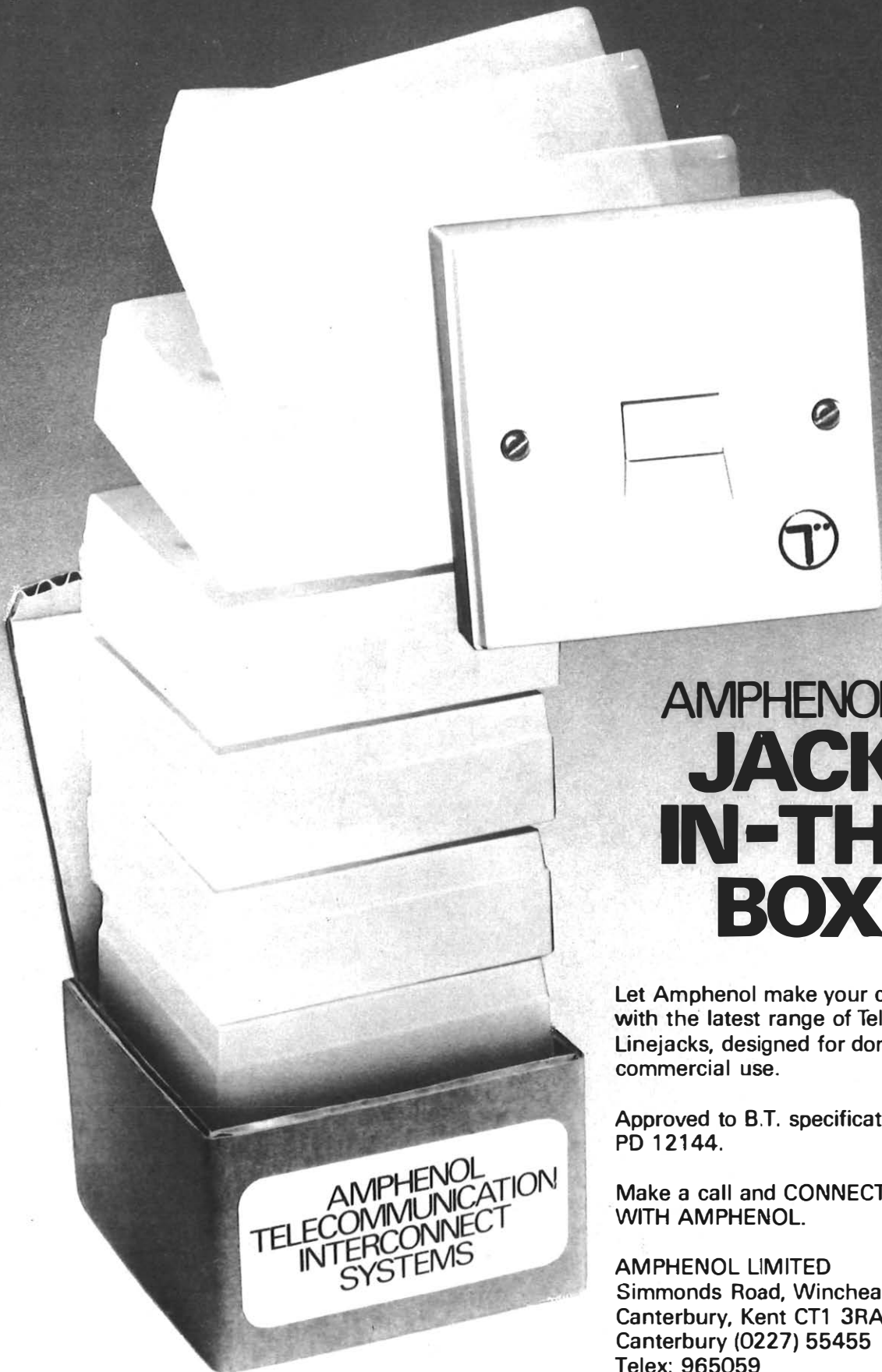


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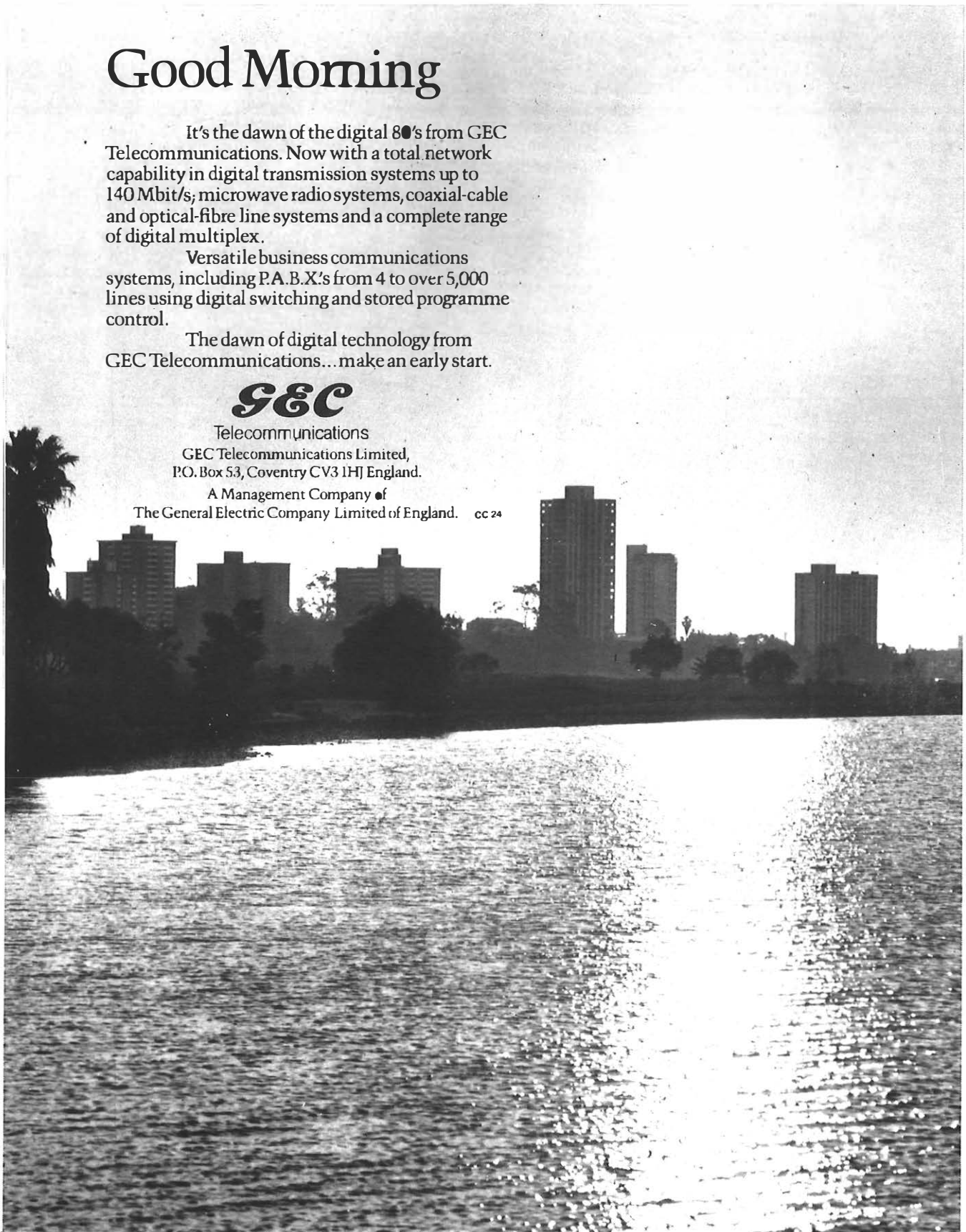
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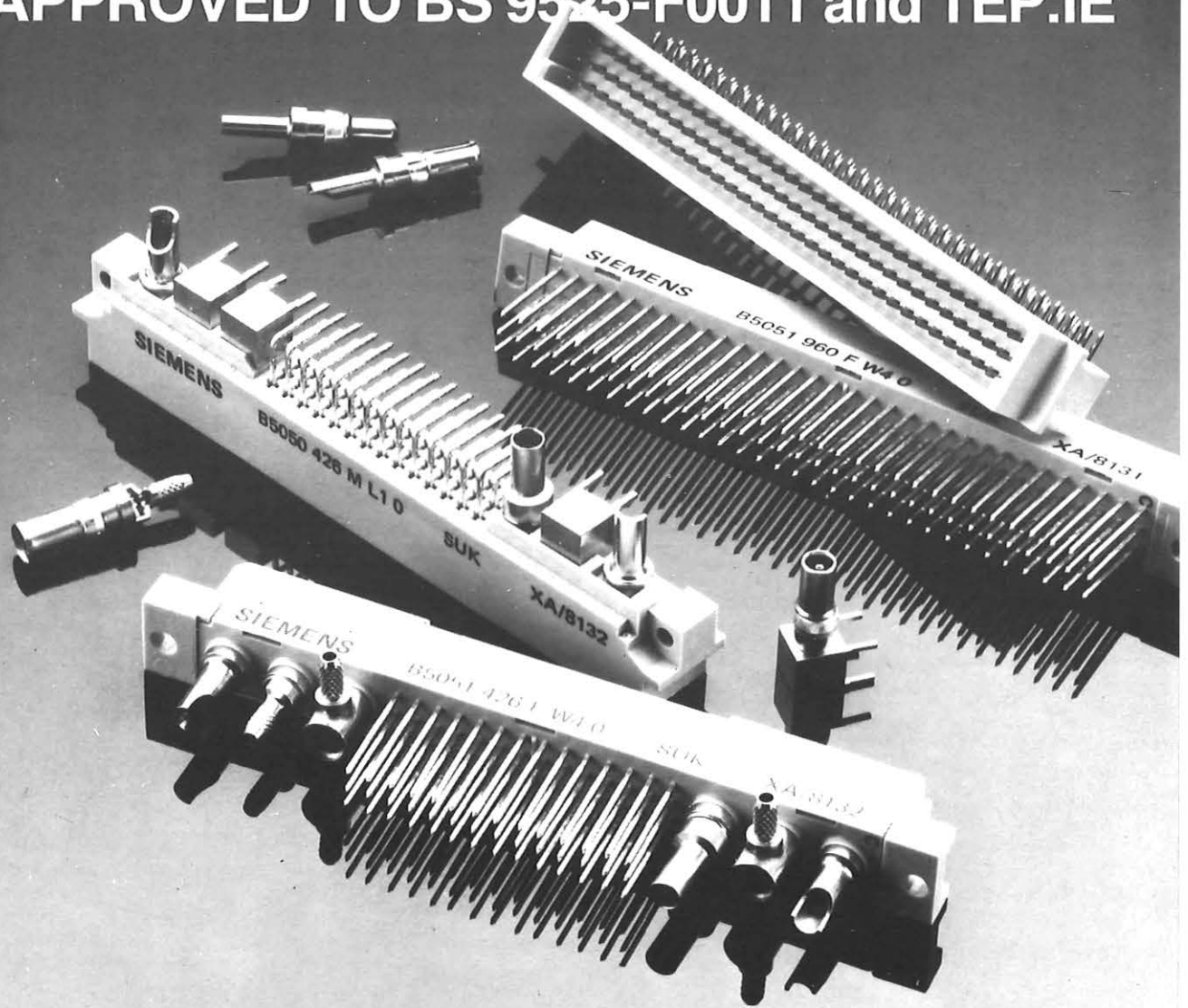
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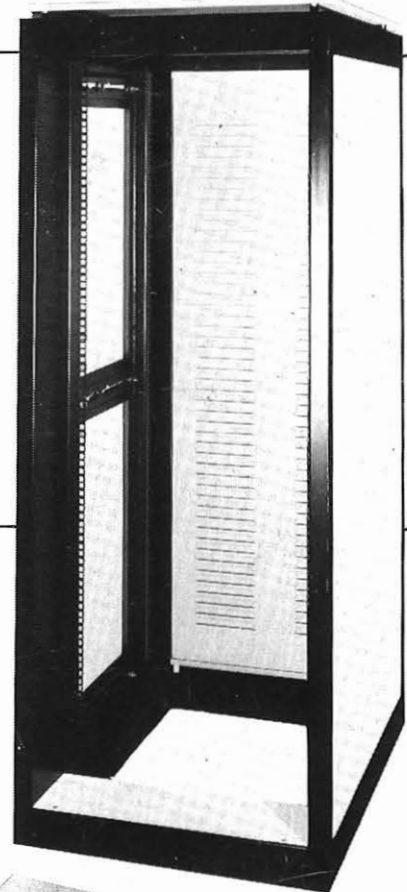
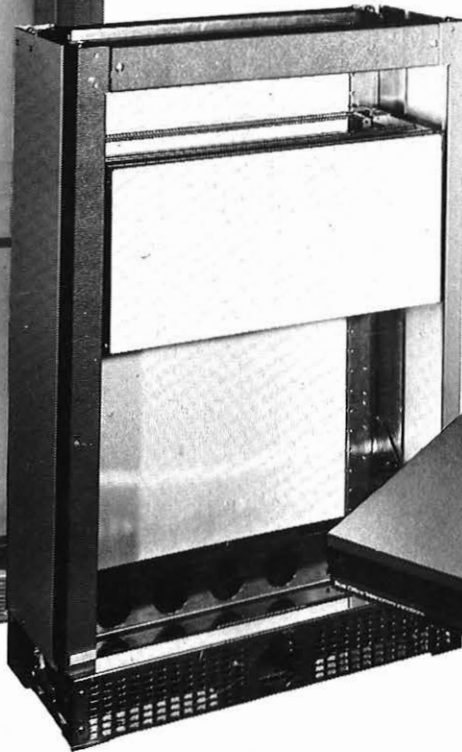
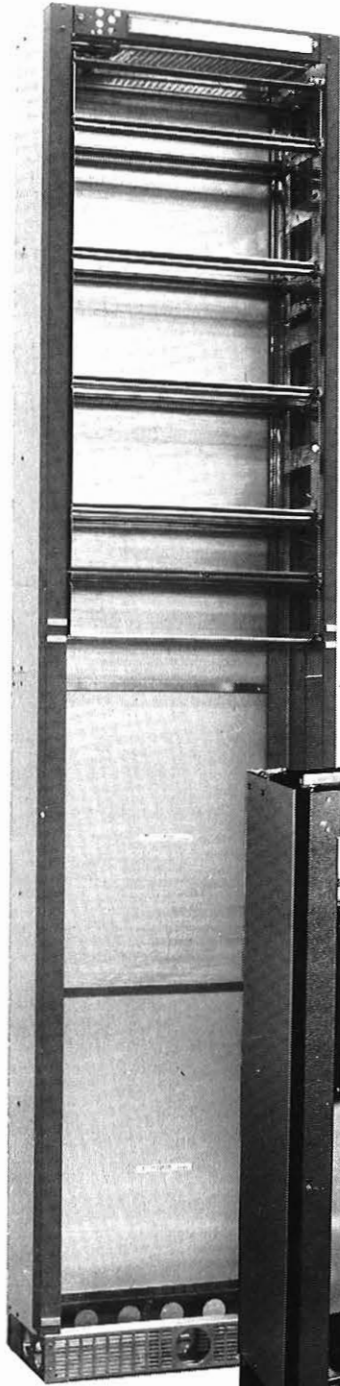
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