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Contents

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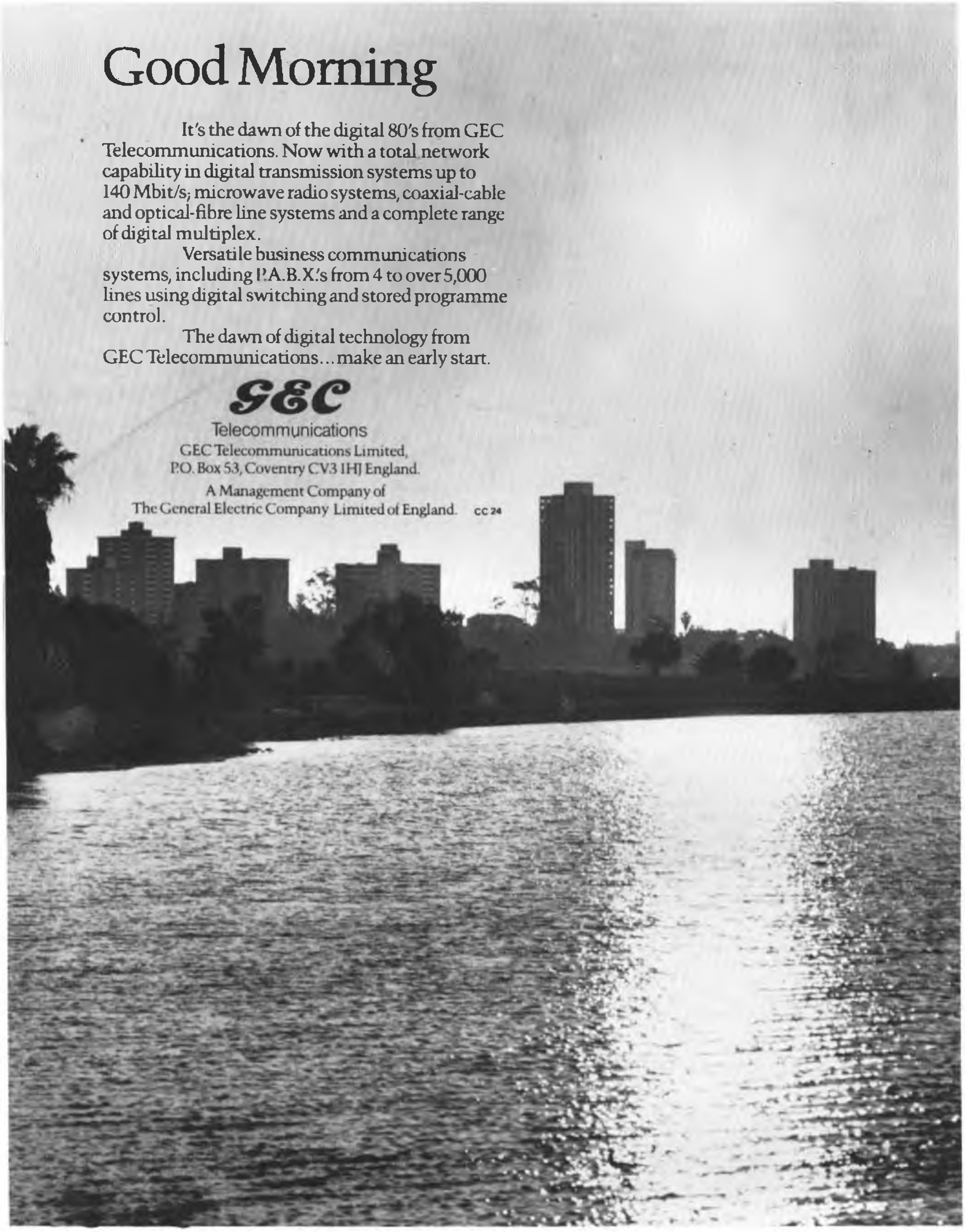
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The Post Office Electrical Engineers' Journal

EDITORIAL

Members of the Institution of Post Office Electrical Engineers (IPOEE) will be well aware of the proposed legislation which will divide the British Post Office (BPO) into two independent corporations: it is proposed that one will have the formal title of *British Telecommunications*, and will handle the operation of telecommunications and data processing services; the other will handle postal and other services at present operated by the BPO. However, the significance of the proposed changes (which will eventually be reflected in a change to the title of the IPOEE and the *Journal*) may not be so obvious to our external readers; in particular, to the overseas readership (the *Journal* is distributed to over 100 countries).

There can be no legal change from the title *Post Office* until the UK Parliament passes the legislation necessary to create the new corporations. Therefore, for the present, the *Journal* will continue the editorial practice of using the title BPO where this appears in articles or other sections of the *Journal*. However, for the BPO telecommunications business, the trading name *British Telecom* is now in general use (see the feature article on page 184 of this issue) and it might be appropriate to use this description at times in the *Journal* but, for the present, in such cases, the term may be considered to be synonymous with the title BPO.

In October 1973, a special issue of the *Journal* was devoted to the description of the 60 MHz FDM transmission system. The provision of the UK 60 MHz frequency-division multiplex (FDM) network is now approaching completion: some aspects of the project are reviewed in an article on page 190 of this issue.

The Operator's Console for the Monarch 120 Digital PABX

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UDC 621.395.2: 621.374

The Monarch 120 is a digital switching call-connect system for use at customers' premises. The overall system organization and switching arrangements have been described in a previous article[1]. This present article describes the operator's console, which is designed to the highest standards to meet the needs of modern business communications centres. The console includes a visual display unit which provides an operator with all the necessary call and system status information.

INTRODUCTION

The Monarch 120 system is a digital switching stored-program controlled (SPC) call connect system for use in customers' premises. The system is now going into service in the British Post Office (BPO) telephone network. In keeping with the central equipment unit[1], the operator's console represents a significant advance in design concept[2] and offers the customer a greater range of facilities than those provided by existing small private automatic branch exchanges (PABXs).

The operator's console is shown in Fig. 1. The console is fully electronic (including the keyboard) and has its own microprocessor to control internal console functions and communication with the central equipment unit.

The major features of the operator's console are as follows:

(*a*) The styling of the console is compatible with modern office and reception area accommodation.

(*b*) The operating procedures are simple and allow rapid handling of calls.

(*c*) A 64-character alphanumeric visual display unit (VDU) is provided. This facility provides full information on the status of the calls being handled.

(*d*) The keyboard is operated by touch-sensitive controls and has no moving parts.

(*e*) The range of facilities provided allows an operator to perform administrative tasks such as revision of extension facilities or abbreviated dialling codes.

(*f*) Data associated with alarms generated by the central equipment unit is received and displayed.

The use of an "intelligent" console having its own microprocessor and program memory permits the introduction of enhanced operator facilities; this feature will allow future market demands to be satisfied without the need for changes to the console hardware.

FIG. 1—Monarch 120: The operator's console

† Product Development Unit, Telecommunications Headquarters

MECHANICAL DESIGN

The console consists of 6 main items of hardware:

(*a*) power unit,
(*b*) processor board,
(*c*) keyboard,
(*d*) VDU assembly,
(*e*) miscellaneous circuits board, and
(*f*) handset.

The 4 electronic modules are mounted on the main console chassis, which is of metal construction and consists of upper and lower halves. The keyboard and the VDU assembly are mounted on the upper half; the processor and the miscellaneous circuits printed-wiring boards (PWBs) are mounted on the lower half. The two halves of the main chassis are hinged together to allow the console to remain operational when in the opened position (see Fig. 2) during maintenance. The power unit has its own metal chassis.

Both the power unit and main chassis assembly are housed within a two-part plastic case, which is moulded in a polycarbonate material.

The console is 555 mm wide and 275 mm deep; the height is 147 mm. A handset rest is provided to the left of the keyboard and there are two jacks on the front of the console for the handset plug. The left-hand jack position is for normal use; the right-hand jack position allows a second handset to be connected during periods of operator training.

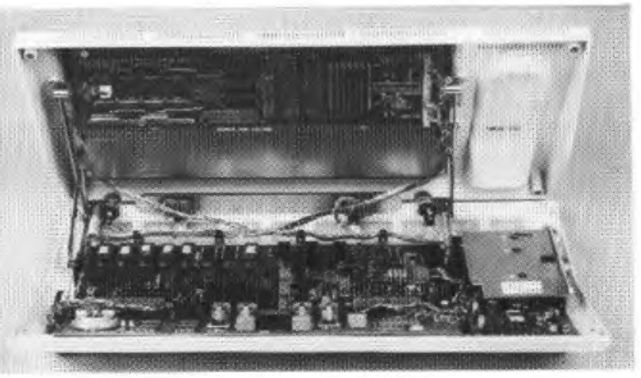


FIG. 2—Console in opened position

The styling of the console is in harmony with that used on the new range of telephone instruments being introduced by the BPO; a Handset No. 16A is provided as standard with each console. Both the case and the handset are in "stone" colour, which is one of a new range approved by the BPO for customer apparatus. The keyboard and VDU filter plate have an anti-reflective black finish, with white lettering to identify keys and the associated light-emitting diodes (LEDs).

The 24-wire cable (which is pre-formed and terminated on insulation displacement type connectors) connecting the console to the central equipment unit enters the console through the rear of the bottom half of the case. Adjacent to the cable entry point is a switch which enables the operator to initiate dropback† service for the whole PABX. This supplements the automatic dropback feature within the central equipment unit, and provides manual over-ride should telephone service be severely interrupted by an equipment or power failure. The dropback switch is located where there is little chance of accidental operation.

The size and location of the PWBs within the console was constrained by the styling of the moulded case, with the result that standardization of PWB size within the console was not possible. Electrical connexion between PWBs is provided by a wiring form, with conductors crimp-jointed to sockets; headers are provided on the PWBs to make it possible to replace individual PWBs within the console.

Cooling of the console is by normal convection and the siting of both PWBs and components within the console gives optimum laminar airflow. Air enters the console case through concealed slots below the front slide switch panel, and exits behind the VDU through a pattern of slots forming part of the upper case moulding.

† Under conditions of system failure exchange lines can be connected directly to designated extensions

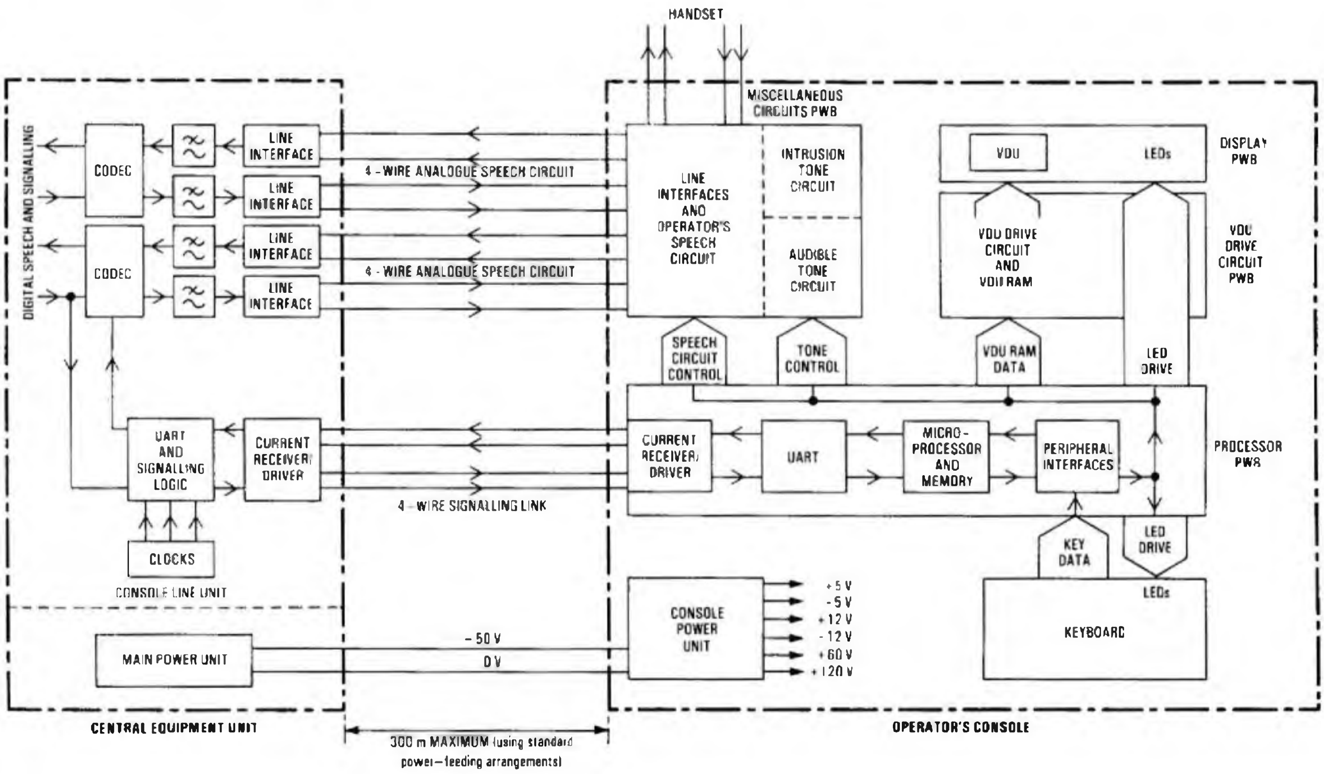
HARDWARE ORGANIZATION

A block diagram of the console and its interface with the central equipment unit is shown in Fig. 3. The console line unit is a 2-port PWB which occupies a position on a line shelf in the central equipment unit. This PWB interfaces with the shelf multiplex in the same way as other line interface PWBs, as described in a previous article[1].

The line unit provides two identical 4-wire analogue speech circuits, each consisting of a codec, filters, a gain adjustment circuit and transformers. The gain adjustment facility allows for compensation to be made for tolerances in the codec and filter performance; only one nominal setting is required for all console line lengths up to the maximum of 300 m.* The transformers provide unbalanced-to-balanced conversion. A DC wetting current is fed through all contacts in the line to the console. The line unit also provides a 4-wire digital signalling link to the console. Data from the signalling output PWB is sent to one port of the line unit, where it is converted from serial transmission and latched into parallel format. A universal asynchronous receiver and transmitter (UART) samples this latched data every 8 ms. Each time this data changes, the UART transmits the data to the console in serial form (with *start*, *stop* and *even parity* bits added) at a rate of 2400 bit/s. The data is transmitted to line via a current driver.

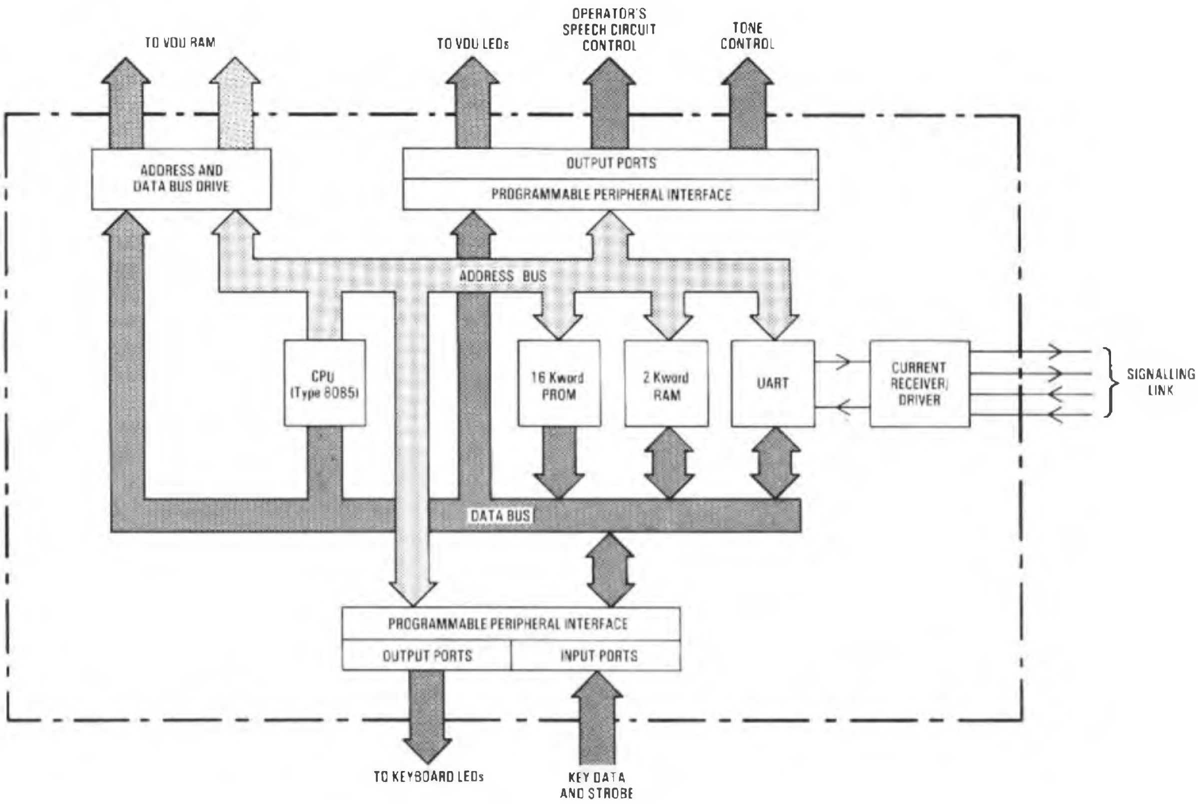
Data in serial form is received from the console at a rate of 2400 bit/s and is forwarded from the current receiver to the UART, which removes the *start*, *stop* and *parity* bits and converts the data to parallel format. This data is latched, converted back to serial format and then multiplexed with the digital speech signal for transmission to the shelf multiplex and to the signalling input PWB.

* Greater line lengths are possible, subject to the provision of suitable power-feeding arrangements



LED: Light-emitting diode
PWB: Printed-wiring board
RAM: Random access memory
UART: Universal asynchronous receiver and transmitter
VDU: Visual display unit

FIG. 3—Block diagram of the console and line unit



CPU: Central processing unit
LED: Light-emitting diode
PROM: Programmable read-only memory
RAM: Random access memory
UART: Universal asynchronous receiver and transmitter
VDU: Visual display unit

FIG. 4—Block diagram of the console processor PWB

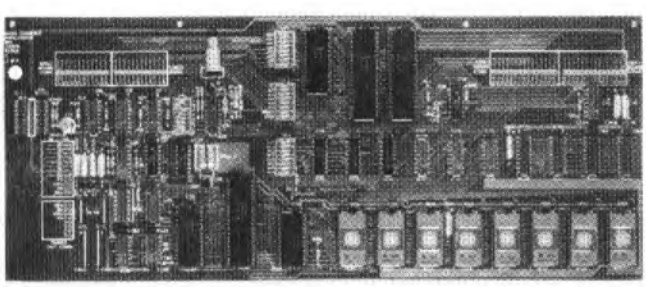


FIG. 5—Console processor PWB

The heart of the console is a single microprocessor (type 8085). A block diagram of the console processor PWB is given in Fig. 4; Fig. 5 shows the PWB. A UART is provided to transmit and receive data over the signalling link to the console line unit. This UART operates in much the same way as the UART in the line unit except that once the data has been converted to parallel format, the data is then presented directly to the console processor via the data bus.

The basic control program for the console processor is stored in a programmable read-only memory (PROM), which has a capacity of 16 Kwords (each of 8 bits). Random access memory (RAM) is used for storing working data, such as received link messages; the RAM capacity is 2 Kwords.

The processor PWB also contains the interfaces to the console peripherals (that is, the VDU, the keyboard and the miscellaneous circuits). The main VDU interface consists of drivers that extend the address bus and the data bus to the VDU RAM, which is located on the VDU drive circuit PWB.

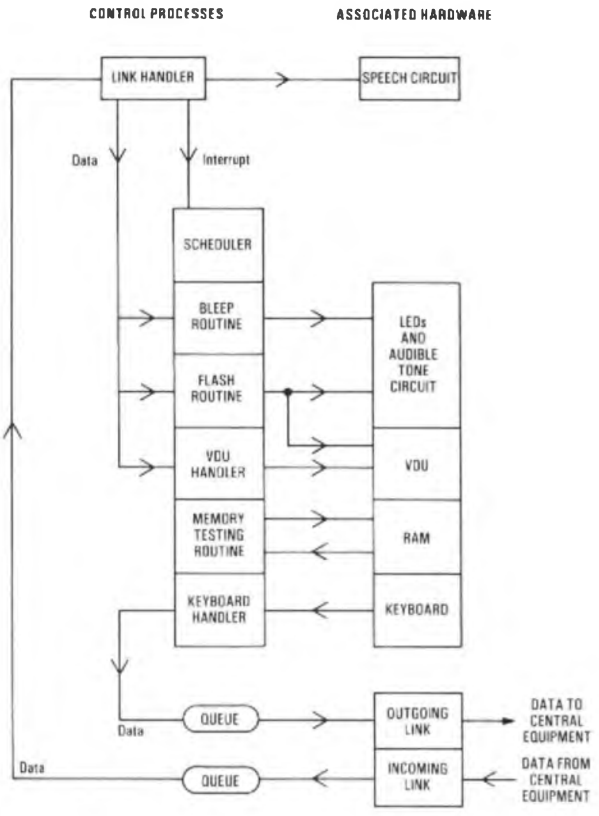
Programmable peripheral interfaces (type 8255) are used for controlling the LEDs on the VDU and keyboard, and for controlling the operator's speech circuit, intrusion tone circuit and audible tone circuit; these circuits are located on the miscellaneous circuits PWB.

The console derives its power from a −50 V DC feed from the central equipment power unit. The console power unit is a DC/DC converter that provides outputs at +5 V, −5 V, +12 V, −12 V, −60 V and −120 V from the −50 V input. Total power dissipation within the console is, typically, 37 W; 12 W is dissipated within the console power unit, 12 W in the VDU and 13 W in the processor, memories and other electronic circuits.

CONTROL

The control program for the console processor consists of a number of routines for controlling the operation of the console peripheral units. The routines are known as the *link handler*, the *VDU handler*, the *keyboard handler*, a *bleep* routine and a *flash* routine. These routines are run periodically, under the control of the scheduler; an exception is the link handler, which runs on an interrupt basis. Fig. 6 shows how these routines relate to the console peripherals and indicates the main flow of data through the console. The control program also contains a memory-testing routine which periodically exercises the console RAM.

When a call is made into the PABX, the central equipment processor scans and controls the line interface being used. If the call has to be directed to the console (for example, an incoming exchange line call), the central equipment processor causes the console line unit to transmit a 3 byte message over the signalling link to the console. The link handler ensures that the data received is forwarded to the other routines to enable appropriate action to be taken.



RAM: Random access memory
VDU: Visual display unit

FIG. 6—Block diagram of the console control structure

In the case of an incoming exchange-line call arriving at the console, the bleep and flash routines ensure that a cadenced audible tone is given to signal the call to the operator and that the LED adjacent to the appropriate key is flashed. This key will subsequently be operated and the data output from the keyboard will be recognized by the keyboard handler, which ensures that a 1 byte message is transmitted over the signalling link to the console line unit and so to the central equipment processor. Receipt of this message will cause the central equipment processor to connect the exchange line port to one of the console line unit ports via the time switch. The processor will also instruct the line unit to transmit a 3 byte message to the console, where the link handler operates as before and ensures that the correct connexions are made within the operator's speech circuit; the VDU handler causes the correct data to be displayed to the operator.

At this stage, the operator can speak to the incoming caller; the identity of the line used and the status of the call are displayed. The operator can proceed to deal with the call, and subsequent keyboard operation causes further interchange of messages over the signalling link. The handling of other types of call and the use of other operator facilities causes similar activity on the signalling link.

The same link-message format is used in all cases (that is, 1 byte from the console to the central equipment and 3 bytes from the central equipment to the console). Most of the messages transmitted from the console merely confirm the operation of a key and give its identity. Messages transmitted from the central equipment contain more varied information, such as line identity and call status, and 3 bytes are normally required to convey this information. When this is not the case, the spare bytes are transmitted with data at a default value, which the console ignores.

When there is no activity on the link due to call handling there is a continual interchange of *idle* signals between the console and the central equipment. In this way, the central equipment processor confirms that the console is functioning correctly; if the *idle* signals from the console cease, then calls are diverted to alternative answering points, which are defined in the central equipment database.

As with the central equipment unit, enhanced facilities for the console can be introduced in the future by making appropriate changes to the control program. The facility is provided for reprogramming the PROM devices (after erasure under ultra-violet light) without removing them from the processor PWB.

The control program for the console does not vary with different sizes of PABX. Information regarding system configuration is transmitted to the console by the central equipment unit and stored in the RAM on the processor PWB. This occurs each time the processor in the central equipment or console is first brought into use; for example, when the console is first powered. Thus, a console recovered from one customer's PABX can immediately be re-used at another Monarch 120 site.

KEYBOARD

The keyboard is shown in Fig. 7. It has a polycarbonate keyplate in which there are depressions for finger location above each key's sensitive area. This keyplate protects the circuits from ingress of dirt or harmful fluids and also carries the legends identifying each key. A PWB carrying the key detection electronics is bonded directly to the underside of the keyplate. A second PWB carrying a 110 kHz oscillator, together with key scanning and encoding circuitry, connects with this assembly. The complete keyboard is 26 mm thick and includes the header connexion to the console wiring form.

The keyboard, which is manufactured by Pye Electro-Devices Ltd., has 46 keys, arranged in three groups:

(*a*) The central group contains a 12-digit keypad and 4 commonly-used function keys, the HOLD, RETRIEVE, CANCEL and WITHDRAW keys.

(*b*) The left-hand group of keys includes 4 keys each for OUTGOING GROUPS and INCOMING GROUPS; 4 other keys – the ASSIST, CALL-IN, WAITING RETURN and SERIES RETURN keys – are used for special categories of incoming calls. Each of the 8 keys concerned with incoming calls has an associated LED on the keyboard. The left-hand group of keys also include the 3 other function keys – TRUNK SELECT, SERIES CALL and VOLUME keys.

(*c*) The right-hand group contains 3 keys concerned with speech circuit control; these are the SPEAK 1, SPEAK 2/KEY INTERNAL and JOIN keys. Also provided are 8 keys associated with special operator facilities – the EXTENSION STATUS, LAST NUMBER REPEAT, METER, LAST CALL RECOVER, RING, STEP-ON, INTRUDE and TIME keys. The 3 remaining keys in the right-hand group are the RECEIVING ATTENTION key (used under alarm conditions), the CONSOLE TEST key (which implements a self testing routine) and a key marked MMI (man-machine interface) which changes the mode of operation of the console to enable it to be used for system administration and fault diagnosis. One spare key is available for use as new facilities are introduced.

FIG. 7—The Monarch 120 keyboard

The keys have no moving parts, and operate on the capacitive touch principle. Each key-detection circuit comprises a resistor, capacitor and transistor; the base of the transistor is connected to a conductive pad on the PWB bonded to the keyplate. A 110 kHz signal is fed to each circuit, which gives a DC level out to the scanning circuit.

When a key is operated, the operator's finger forms the second plate of a capacitor with the conductive pad on the PWB; the keyplate acts as the dielectric. The dielectric constant of polycarbonate and the dimensions of the keyplate are such that the value of the capacitor so formed is about 1 pF, which is in series with the body capacitance to earth (normally between 100 pF and 150 pF).

The additional capacitance to earth thus connected to the base of the transistor is sufficient to cause a shift in the DC level output, which is subsequently recognized by the scanning circuit. Having detected the operation of a key, the encoding circuit presents an 8 bit code (7 data bits plus an even parity bit) to the programmable peripheral interface on the processor PWB, via a parallel data bus. The keyboard sends a strobe signal to the processor to confirm when key data can be read from the bus: this action occurs after a persistence check of 10 ms (minimum).

The keyplate dimensions and material have been carefully selected to give the required key sensitivity, although setting up adjustment is provided by a potentiometer at the front of the keyboard which alters the level of the 110 kHz signal. This adjustment also ensures that the sensitive area of each key is confined to the depression in the keyplate.

Because there are no moving parts in the key it is necessary to provide a substitute for the mechanical feedback given by conventional keys. This is done by sounding an audible tone to confirm each key operation; operator reaction to this method has so far proved very favourable.

VISUAL DISPLAY UNIT

A DC electroluminescent (DCEL) panel is used for the console VDU[4,5]. This panel gives an alphanumeric display in 4 rows of 16 characters, each character being formed from a 5 × 7 dot matrix. The display area is 76 mm wide by 34 mm high, each character is approximately 3 mm wide and 4 mm high. The DCEL panel is supplied by GEC Hirst Research Centre and Phosphor Products Ltd.

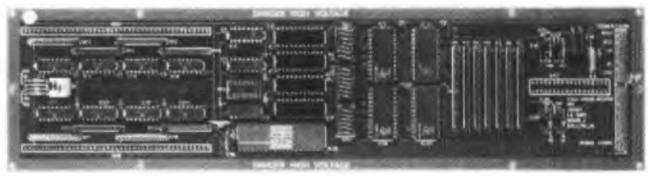
The front viewing panel of the VDU consists of a glass plate, on the rear face of which are deposited layers of material (including phosphor) which form an electrically-conducting grid pattern. The rear face of the plate is protected from atmospheric moisture by further glass encapsulation.

The panel is clamped onto a PWB, and electrical connexions to the conducting grid are made via two elastomeric connectors positioned along the top and bottom edges of the panel. This PWB is also used to mount 5 LEDs, which indicate alarm conditions and system status (see Fig. 8(*a*)). The drive circuitry for the VDU is accommodated on a second PWB (see Fig. 8(*b*)) which connects directly with the PWB on which the panel is mounted.

When a potential (above a certain threshold value) is applied between a horizontal row and a vertical column on the conducting grid, the phosphor dot at their point of intersection will emit light; the VDU drive circuitry applies a positive 120 V potential to the row, and earth potential to the column. In the idle condition, a positive 60 V potential is applied to both row and column and the dot is not illuminated. The threshold potential required to illuminate a dot is approximately 70 V.

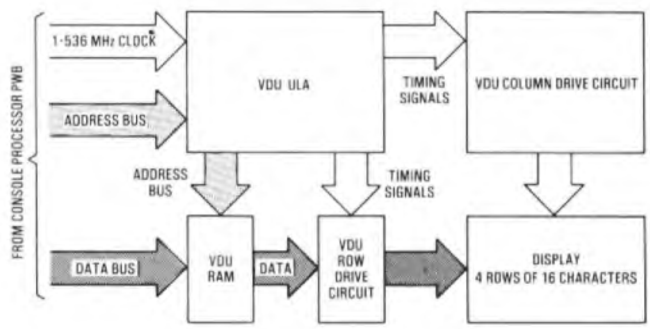
A block diagram of the VDU drive circuit is shown in Fig. 9. To drive all the dots on the VDU (2240 in total) it is necessary to use multiplexing techniques. The columns are continually scanned such that each is selected in turn and driven from +60 V potential. The VDU (80 columns) is scanned at a rate of 600 Hz; thus, within each scan period (1·67 ms), each column is selected for 21 μs. During this period, a +120 V potential is applied to those rows containing the dots to be illuminated. (The remaining dots in the selected column have a +60 V potential on the row, but this is below the threshold required to illuminate them.)

(*a*) Display PWB



(*b*) VDU drive circuit PWB

FIG. 8—Visual display unit PWBs



PWB: Printed-wiring board
RAM: Random access memory
ULA: Uncommitted logic array
VDU: Visual display unit

FIG. 9—Block diagram of the VDU drive circuit

When the console processor responds to an event such as a key operation or an incoming link message from the central equipment unit, one of the processor's activities is the control of the VDU. The VDU has its own complementary metal-oxide semiconductor (CMOS) static RAM, in which there is stored one bit of data corresponding to each dot on the VDU. To display a message on the VDU the processor writes data into the RAM, which effectively becomes a memory map of the display.

To prevent corrupted data being displayed continually, the processor completely refreshes the VDU RAM once every second. This is done both when the VDU is clear and when a message is being displayed.

An uncommitted logic array (ULA) uses a 1·536 MHz clock waveform, sent from the processor PWB, to derive all the timing signals required for the RAM, row drive circuit and column drive circuit. The ULA also controls access to the RAM, which has to be shared between *write* periods from the the processor and *read* periods from the row drive circuit. If, for example, the ULA has just caused the column drive circuit to select the first column on the VDU then, within the 21 μs selection period, the ULA will control the RAM addressing so that the appropriate data (28 bits) is read from the RAM and latched into the row drive circuit, which then translates the logical levels *zero* and *one* to the +60 V and +120 V potentials to be applied to the panel. The appropriate dots in the selected column will then be illuminated.

The row drivers are hybrid devices; each 14-pin single-in-line package contains circuitry to drive 4 rows of dots, therefore 7 hybrid packages are required for the whole VDU.

After the dots have been illuminated for a while, the ULA sends a signal to the row drive circuit to clear the +120 V potential and restore the +60 V potential for all the rows. The period of time in which this action is initiated can be varied by setting a switch on the VDU drive circuit PWB, thus allowing the brightness of the display to be controlled; the period is, typically, 8 μs, giving a dot duty cycle of approximately 0·5%.

After the 21 μs column select period has elapsed, the ULA will cause the column drive circuit to select the second column on the VDU and the whole process is repeated. The ULA addresses a different area of the RAM, holding the data corresponding to the dots in the second column. This cycle is repeated 80 times for each complete scan of the VDU.

The light output from a phosphor dot decays to approximately 15% of its maximum before the driving potential of +120 V is re-applied (after 1·67 ms). However, the display appears completely free of flicker because of the high scan rate used.

The light emitted by the panel is yellow in colour, and is closely matched to that part of the spectrum in which the human eye has its maximum sensitivity. A grey filter plate is provided in front of the VDU; this plate has an anti-reflective finish on the front surface and also serves to improve the contrast ratio of the display. The maximum brightness of the panel could be 180 candela/m^2 at 120 V, but the brightness is set below this value on the VDU drive PWB. The brightness of the panel display is further reduced by transmission losses through the VDU filter plate; in this way, the brightness apparent to the operator is about 70 candela/m^2.

OPERATOR'S SPEECH CIRCUIT

The two 4-wire analogue speech circuits from the central equipment unit are terminated in the console on the miscellaneous circuits PWB. The speech circuits interface with the operator's speech circuit through transformers, which perform the same function as those in the console line unit.

The operator's speech circuit consists of a 20-pin dual-in-line thick-film hybrid package (containing an array of resistors, CMOS bilateral switches and operational amplifiers) and a few discrete components. The CMOS switches are controlled by the console processor and are used to connect either or both of the 4-wire circuits to the transmitter and receiver in the handset under the control of the SPEAK 1, SPEAK 2 and JOIN keys, thus providing the normal operator facility of call-splitting and joining. Another CMOS switch is used to select a different gain setting for the operational amplifier in the path to the handset receiver, under the control of the VOLUME key. Thus the operator can increase the loudness of calls by 6 dB, if required. The hybrid package contains a feedback path between transmitter and receiver connexions to provide the correct level of sidetone on the handset.

Intrusion tone is generated on the miscellaneous circuits PWB and, when appropriate, this tone is injected into a 3-party call via the transmitter input to the speech circuit hybrid.

CONSOLE FACILITIES

One of the major features of the Monarch 120 system is the wider range of extension and operator facilities offered in comparison with existing small PABXs[3]. The Monarch 120 operator's console provides 'key-per-function' working, rather than 'key-per-line' (as used on many other systems), and allows simple functional control of the PABX for both experienced and inexperienced operators. This feature is important at smaller installations where the level of telephone traffic is relatively low and where the operator may also have other duties as a receptionist or secretary.

Lines incoming to the PABX (exchange lines and inter-PBX circuits) can be arranged in up to 4 separate groups, as defined in the system database. Successive calls within each group are queued automatically in order of arrival, and a faster LED flash rate indicates that more than one call is awaiting answer. The operator can therefore choose which call queue will be handled, by operating the appropriate INCOMING GROUP key; the VDU then shows the identity of the line connected.

To extend the call inwards, the operator merely keys the extension number, which is also shown on the VDU together with the status of the line; for example, the word *RINGING* is indicated on the VDU. In this case, the operator can either wait to announce the call to the extension or can operate the WITHDRAW key, leaving the incoming caller receiving ringing tone. If the call remains unanswered for 30 s, the call reverts automatically to the console, where it is placed on the "WAITING RETURN" queue.

If the extension being called is busy, the VDU shows *BUSY, ACTION?*. In this case, the operator can redirect the call or use the INTRUDE key to break into the existing call (warn tone is introduced at this stage) to announce that a call is waiting. Alternatively, the incoming call could be put into a "HOLD" status until further attempts to connect the call prove successful; in this case, the legend *H1* is flashed in one corner of the VDU to remind the operator that one call has been held on the console. More than one call can be held at a time, in which case the number of calls held is indicated by *H2*, *H3* etc. on the VDU. The RETRIEVE key is used when the operator wishes to speak to a held call; successive operation of the HOLD and RETRIEVE keys selects the held calls on a cyclic basis.

Calls to the operator from PABX extensions are placed on the ASSIST queue; those from PABX extensions already engaged on a call and making an enquiry to the operator are placed on the "CALL-IN" queue.

If the party on an "INCOMING GROUP" call states that subsequent calls to other extensions will be required, then the operator can set up a "SERIES CALL". On conclusion of the first call, the incoming call is placed on the "SERIES RETURN" queue on the console, so that the operator can set up the next extension call.

In answering calls at the console, the operator can choose to speak privately to either party involved, by operating the SPEAK 1 or SPEAK 2 key, and then restore a 3-way connexion by using the JOIN key. The VDU shows the speech connexion status of both parties on the call. The operator can also increase the loudness of a call to the console by operating the VOLUME key; when there is no call being handled, this key is used to alter the volume of the audible tones given to indicate incoming calls and confirm key operation (these can be individually adjusted).

Outgoing exchange and inter-PBX lines are also arranged in up to 4 outgoing groups, which are defined in the system database. If more than 4 groups are required, then access to these can be made using a digit code on the keypad. When necessary, the TRUNK SELECT key (followed by a digit code) can be used to seize a particular line within a group; this would normally be done whilst trying to identify a faulty line.

If an outgoing group call does not mature, a further attempt can be made by re-operating the appropriate OUTGOING GROUP key followed by the LAST NUMBER REPEAT key. This causes the last number keyed out over a line in that group to be transmitted again.

The operator can decide to meter an outgoing call set up via the console. On conclusion of a metered call, the audible tone is sounded, and re-operation of the METER key causes the VDU to display the extension identity and the number of metered units recorded on that call.

The operator uses the CANCEL key to negate the previous action; for example, if an incorrect digit has been keyed. Operation of the LAST CALL RECOVER key re-connects the last call handled to the console, providing that the call has not matured in the meantime; it is therefore possible to negate an operation of the WITHDRAW key.

The Monarch 120 system offers various call diversion facilities to extension users, including divert all calls (DAC), divert on no reply (DNR) and divert on busy (DOB). The operator can override these diversions where appropriate, by using the RING and STEP-ON keys. For example, if the operator calls a free extension which has invoked DAC, the VDU will show *EXTN 234, DAC, ACTION?* The diversion can be overridden by operating the RING key or followed by operating the STEP-ON key. In the latter case, the VDU will then show the identity of the new extension. When DNR has been invoked, diversion would normally occur after 10 s. However, when the operator calls an extension which has invoked DNR, the diversion only occurs if and when the STEP-ON key is operated; the VDU shows the identity of the new extension, as before. Similarly, when DOB has been invoked, and the extension called from the console is busy, the diversion occurs only after operation of the STEP-ON key. These facilities ensure that the operator can offer incoming callers the choice of following a call diversion, or refusing if they only wish to speak with a particular person.

Use of the EXTENSION STATUS key allows the operator to determine the status of any extension without changing the condition of the line; in particular, if the extension is free, the telephone is not rung.

The operator can use the TIME key to display both time and date on the VDU, these being continually updated by data transmitted over the signalling link from the central equipment.

Two slide switches are provided on the front of the console to enable the console to be switched inactive or completely powered down. Switching the console to the inactive state normally initiates night-service working for the PABX; call handling arrangements would be defined in the system data base.

When it is switched inactive, a routine of tests can be run on the console by using the CONSOLE TEST key. This flashes all the LEDs and causes the VDU to give a schematic display of the keyboard; this display is amended after successful operation of each key.

Two LEDs are provided adjacent to the VDU to indicate the arrival of *urgent* and *non-urgent* alarm messages; an audible tone is also given.

Operation of the RECEIVING ATTENTION key cancels the alarm indication and causes the fault parameters to be displayed on the VDU. The operator can relay this information to the service engineer when the fault is reported. In most cases this will be sufficient to identify hardware faults down to PWB level so that the correct replacement item can be brought to site.

The MMI (man-machine interface) key changes the function of the console to that of a simple terminal which can be used to carry out system diagnosis and administration. MMI instructions are implemented by use of a range of special codes sent from the digit keypad; the VDU is extensively used in MMI to display system data. Various levels of access are provided into MMI, each requiring a password to be keyed-in prior to using the MMI facilities. The customer level is the most restricted; service and specialist levels offer increasingly sophisticated facilities. Some of the functions available at customer level are:

(*a*) definition of system abbreviated dialling codes,
(*b*) activation/deactivation of extensions,
(*c*) definition of extension hunting groups,
(*d*) displaying/resetting meter counts,
(*e*) revision of directory numbers,
(*f*) listing of extension/trunk attributes, and
(*g*) resetting system time/date.

At the service level, some of the functions available are

(*a*) clearing system fault records,
(*b*) resetting alarms,
(*c*) running diagnostic tests, and
(*d*) displaying port status.

At the specialist level, some of the functions are

(*a*) clearing facility statistics,
(*b*) setting fault analysis, and
(*c*) examining memory contents.

These lists are by no means exhaustive, and demonstrate that the console has wide ranging uses in the MMI mode. This avoids the expense of providing a dedicated terminal on site and allows the customer to carry out administrative tasks that would otherwise require the attendance of a service engineer. The use of MMI during system maintenance will be the subject of a later article in the *Journal*.

CONCLUSIONS

This article has described what is probably the world's most advanced operator's console for small PABXs.

After 4 years of development and field trials, the production and delivery of Monarch 120 consoles are now well under way; together with the central equipment units, these are being manufactured by Plessey Office Systems at Nottingham, and GEC Telecommunications (Private Systems Division) at Coventry, which are also marketing the system abroad under its earlier title of Customer Digital Switching System No. 1 (CDSS1).

Further development of the console is already under way to ensure that it continues to meet customer requirements in what is becoming an increasingly competitive and demanding area of the telecommunications business.

ACKNOWLEDGEMENTS

The author wishes to thank his colleagues in the BPO and UK Industry who have contributed to the successful development of the Monarch 120 operator's console.

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High-Speed Digital Transmission in the British Post Office Coaxial Network

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The British Post Office is moving steadily towards a fully integrated digital switching and transmission network. This article examines some of the problems associated with the conversion of the main coaxial transmission network to digital operation and considers the latent potential for application at bit rates up to 565 Mbit/s and above.

INTRODUCTION

Over the past four decades, the British Post Office (BPO) has installed a network of approximately 200 000 pair-kilometres of coaxial cable, of which 79% is of the 1·2/4·4 mm type and the remainder is 2·6/9·5 mm. As the network has evolved, it has been used for analogue transmission systems of increasing bandwidth, commencing at 1·3 MHz, through to systems of 2·6 MHz, 4 MHz, 12 MHz and, finally, 60 MHz[1].

Following the UK Trunk Task Force recommendation[2] that the BPO should progress towards a fully integrated digital switching and transmission network, a programme for meeting network growth by using 120 Mbit/s digital transmission[3, 4] was initiated. The new 120 Mbit/s systems[5] use the same nominal repeater spacings as the existing 12 MHz frequency-division multiplex (FDM) systems; that is, 2 km on 1·2/4·4 mm cable and 4·5 km on 2·6/9·5 mm cable. The value of 120 Mbit/s was chosen before standardization by the International Telegraph and Telephone Consultative Committee (CCITT) at about 140 Mbit/s for the fourth order of the digital hierarchy. At that time, it was considered that 120 Mbit/s was the maximum rate that could reliably be achieved within the existing power feeding limits of the BPO network at the repeater spacing required to permit utilization of existing repeater accommodation. However, as a result of further research on line codes and coaxial cable characteristics, it subsequently proved possible to meet the repeater spacing requirements at the 140 Mbit/s rate[6], and so future digital transmission capacity on coaxial cables will be provided by CCITT standardized 140 Mbit/s digital line sections (DLSs)[3].

In 1973, when the third phase of the main network development programme was being formulated, circuit demands were buoyant and a need was foreseen for a higher-capacity DLS to be available in the early-1980s[3]. As a result, research was undertaken in the BPO and Industry to develop a 565 Mbit/s system[7,8] for use on either 1·2/4·4 mm or 2·6/9·5 mm coaxial cables. Subsequently, because of the world economic recession, the estimated demand for new circuits fell, thereby delaying the requirements for systems of this capacity. Progress on the development of optical fibre systems now suggests that optical systems may be more economic when the requirements for very-high-capacity DLSs eventually arise.

Consequently, there remains doubt as to whether 565 Mbit/s coaxial systems will be required; much will depend on time scales and comparative costs. In the latter context, two basically different situations must be considered:

(*a*) provision of new routes using either optical or coaxial systems, and

(*b*) provision of a new optical system compared with the conversion of an existing coaxial system to 565 Mbit/s operation.

In the former case, there seems little doubt that optical systems will be the more competitive, but it is not yet certain that this will also apply in the latter case. In particular, spare high-quality coaxial pairs in the cables provided recently for 60 MHz FDM systems may be worth exploiting at bit rates of 565 Mbit/s or above.

The future demand for new coaxial cable is expected to decline rapidly when more competitive optical fibre systems become available. From the coaxial cable viewpoint therefore the problem is one of exploiting existing cables, rather than considering improved cable designs better suited to digital transmission.

This article reviews the digital transmission capabilities of the BPO coaxial cable network, and considers some of the specific cable problems involved in providing 140 Mbit/s and 565 Mbit/s transmission systems.

HIGH-FREQUENCY COAXIAL CABLE CHARACTERISTICS

The results of earlier high-frequency studies on coaxial pair cables[9] indicated that the ultimate limiting factors for high-bit-rate transmission arise from the non-uniform nature of the cables. Sources of cable non-uniformity and the resulting echoes produced have been discussed previously[9] and classified into two main groups: random discrete effects, and coherent periodic echo sources resulting from the repetitive nature of manufacturing process. These both produce a degradation in the transmission error probability performance that becomes increasingly severe as bit rates are increased and ultimately set an upper limit to the operational bit rates that can be achieved.

Basic Transmission Characteristics

An accurate knowledge of the basic transmission characteristics—attenuation, phase delay, characteristic impedance and crosstalk—is fundamental to the design of all types of system. Fortunately, these characteristics are more consistent than those of impedance irregularity and have been adequately defined over the required frequency ranges for both types of cable[10].

Analysis of UK 1·2/4·4 mm Impedance Irregularity Data

To ensure that a realistic estimate of the transmission capabilities of the UK coaxial network was made, all available cable test records from UK manufacturers were used, together with those from the BPO Research and Operational Programming Departments'* cable and field testing programmes[10,11]. This data included a total of 112 cables, with a detailed record

† Research Department, Telecommunications Headquarters

* Now part of Transmission Department, Telecommunications Headquarters

of the characteristics of 961 coaxial pair ends of 1·2/4·4 mm cable. This gives a representative sample of about 1% of the total installed 1·2/4·4 mm coaxial cable network.

General Data Format

The total data available on impedance irregularities was presented in a number of different forms including: pulse-echo return loss[12], conventional time-domain reflectometry (TDR)[13] tests, carrier wave (CW) return loss[14], CW burst return loss[15], CW burst forward echo[9], excess attenuation[16] and, finally, through pulse echo[17]. However, for the coherent echo data, the CW burst return loss measurements provided the vast majority of the information. It was therefore decided to convert all the data to this format for the purposes of analysis and system calculations.

The discrete echo results were extracted from the pulse-echo return-loss data and analysed separately.

Computer-Aided Analysis

As can be seen from the example in Fig. 1, practical cables have extremely complex return-loss/frequency characteristics —commonly referred to as *regularity return loss* (RRL); it therefore proved necessary to extract a limited amount of information for analysis. The important features in the RRL characteristics involve only two parameters: the frequency and amplitude of RRL resonances. For pulse-echo data, the principal feature is the amplitude of any discrete echo detected, as shown in Fig. 2.

Computer assistance was necessary to analyse the large number of results.

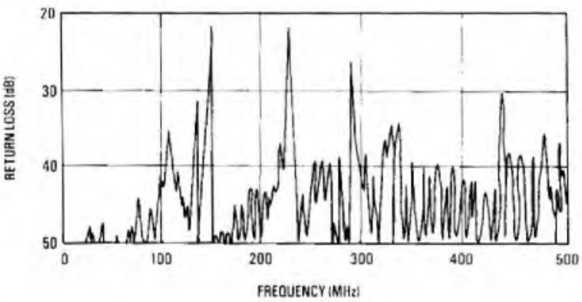


FIG. 1—CW burst return loss profile of a 1·2/4·4 mm coaxial pair

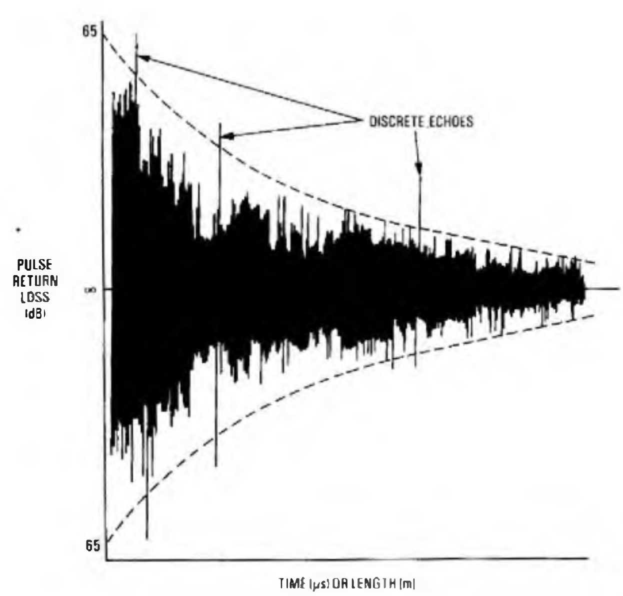


FIG. 2—Pulse echo response of a typical coaxial pair

The General Form of Data Analysis

The data format produced by the computer sifting program (Fig. 3) shows the probability density function (PDF) of resonant frequencies of RRL spikes up to 500 MHz, while Fig. 4(*a*) gives the PDF of the amplitude of the spikes. As a further example, Fig. 5(*a*) gives the PDF of the 2 ns pulse-echo amplitudes from the same sample. If the results in Figs. 4(*a*)

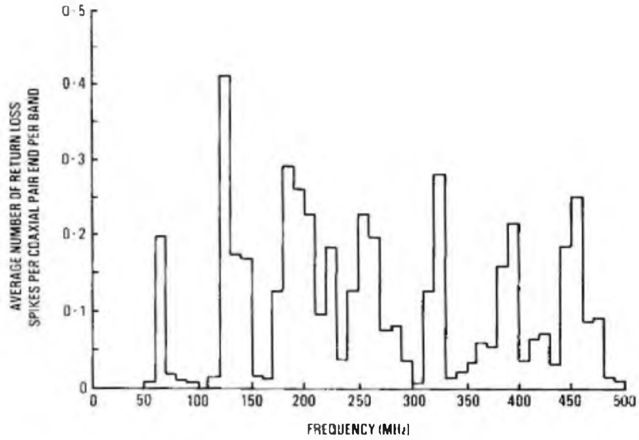
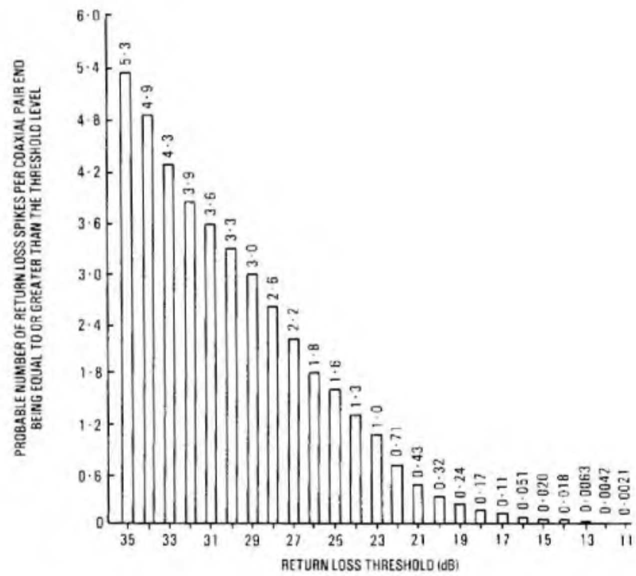
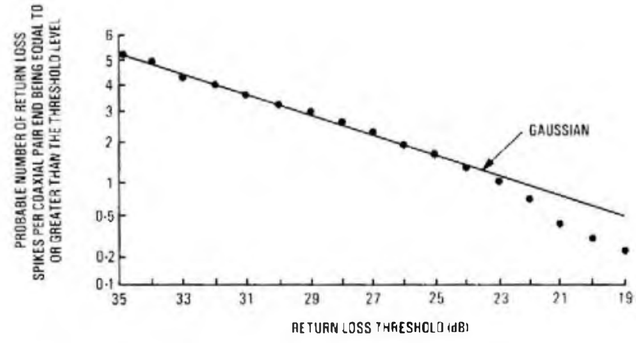


FIG. 3—Example of CW return loss analysis result: resonant frequency distribution



(*a*) On linear scale



(*b*) On probability scale

FIG. 4—CW return loss amplitude distribution

and 5(*a*) are plotted on a probability scale, a fairly linear, and thus Gaussian, distribution results, as shown in Figs. 4(*b*) and 5(*b*).

It can be seen, from the two examples given, that the departure from the Gaussian distribution becomes significant only for very high echo levels; that is, for extreme cases, where there are proportionately fewer contributors. Clearly the true PDF, for a 100% sample, must be of a truncated Gaussian form, as production cable tests will have rejected any extreme values above this region.

2·6/9·5 mm Cable Data

In general, the 2·6/9·5 mm cables fall into two distinct classes: those installed during the initial stages of the formation of the coaxial network, and those installed much later for the 60 MHz FDM routes.

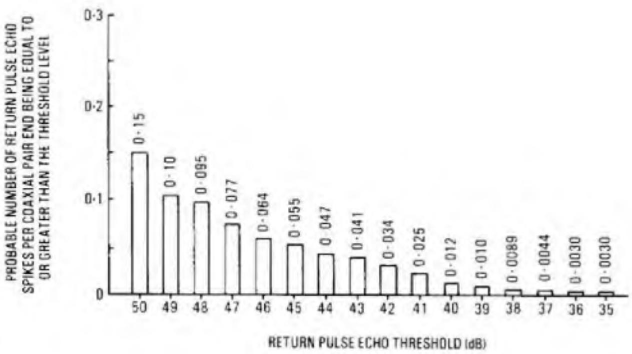
Only limited high-frequency testing has been undertaken on the former, while very full data is available from factory and installation test records for the cables installed on the 60 MHz routes. The 60 MHz cables are not directly comparable with the earlier 2·6/9·5 mm cables because they were manufactured to a specification intended to meet not only the 60 MHz FDM system requirements, but also to provide a digital transmission capability over a 500 MHz frequency spectrum.

Although it has not proved possible to put the 2·6/9·5 mm cable data on computer file for detailed analysis, the following broad conclusions can be drawn from a study of the available measurement data:

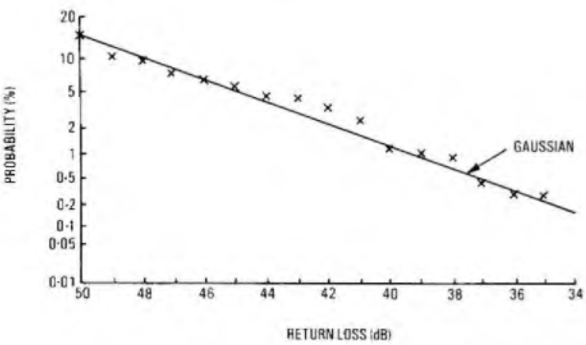
(*a*) The basic transmission characteristics of all the 2·6/9·5 mm cables are known with sufficient accuracy for system design purposes.

(*b*) The impedance irregularity characteristics of the pre-60 MHz 2·6/9·5 mm cables are broadly comparable with those of the 1·2/4·4 mm cables.

(*c*) The cables for the 60 MHz network have significantly better impedance uniformity than other types and would be the most suitable for very high bit-rate digital transmission.



(*a*) On linear scale



(*b*) On probability scale

FIG. 5—Pulse echo (2 ns) amplitude distribution

SYSTEM PERFORMANCE PREDICTIONS FOR 120/140 Mbit/s TRANSMISSION

The main findings of the RRL data analysis studies on UK 1·2/4·4 mm and 2·6/9·5 mm coaxial cables for 120/140 Mbit/s transmission were that:

(*a*) echoes from randomly-spaced irregularities are in general sufficiently small to be neglected—this also applies for 565 Mbit/s transmission, and

(*b*) all significant echoes from periodic irregularities fell outside the spectrum of the 120/140 Mbit/s systems; this was not the case for 565 Mbit/s transmission and this aspect is discussed later.

The main constraints on the design of the 120/140 Mbit/s systems did not result therefore from impedence irregularities[18]; these arose from the requirement to use the same repeater spacings as the 12 MHz FDM systems, while also meeting the power-feeding limits in the BPO network[3]. However, these requirements were satisfactorily attained; 120 Mbit/s systems are currently being installed, and 140 Mbit/s systems are expected to be available in the near future.

INCIPIENT CABLE FAULTS

Although the overall transmission characteristics of the BPO coaxial network were found to be fundamentally suitable for digital transmission and presented no major problems in the design of the 120/140 Mbit/s DLS, unexpected problems arose because of the presence of intermittent or incipient faults. These faults, which were of the type commonly referred to as *dry-joints*, can occur in the cable terminations (mainly at sealing ends and back-joints), or in the main cable joints.

Intermittent faults of this type are troublesome on both analogue and digital systems. They produce noise bursts or level variations on analogue systems, and can cause bursts of errors, leading to possible loss of framing alignment in extreme cases, on digital systems. In the case of severe intermittent faults, digital transmission is, in some respects, less robust than analogue transmission and it is important that faults of this type are eliminated for digital transmission at all bit rates.

Pulse Crosstalk Test

To permit rapid location of intermittent faults, a new test method was developed by the BPO and is illustrated in Fig. 6. The method is termed *outer injection pulse crosstalk test*[19] and is currently in use in the field. In this method, pulses (typically of 10 ns duration) are injected into the coaxial outer circuit. Crosstalk coupling, resulting from the longitudinal impedance of a dry joint, is detected on the normal inner/outer circuit of the coaxial pair under test. The fault position can be deter-

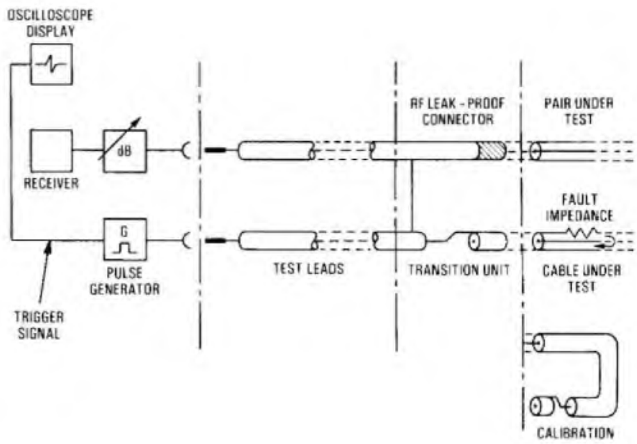


FIG. 6—Block diagram of pulse crosstalk measurement

mined from the measured time delay and the known phase-delay characteristics.

The pulse crosstalk test has proved very successful in the field for locating faulty terminations, and the Regions are being equipped with this type of test equipment. Unfortunately, the test is limited to a range of about 40 m because of the high attenuation, dispersion and poor uniformity of the coaxial outer circuit.

To locate dry-joint faults anywhere within a repeater section, two other possible test methods, swept-frequency crosstalk and an intermodulation technique, are being studied.

Swept-Frequency Crosstalk Measurement

The proposed method for swept-frequency crosstalk measurement also uses outer injection (Fig. 7). An appropriate swept-frequency signal is injected onto a pair of outer conductors. Crosstalk resulting from coupling produced by longitudinal fault impedances (dry joints) is detected using a high-gain selective detector connected to the inner conductor of one of these two pairs. A reference length of cable is inserted between the coaxial pair under test and the detector to ensure that adequate phase change is obtained when locating faults close to the testing end.

A reference signal is also injected into the detector circuit via a variable attenuator. On detection of a crosstalk signal, the attenuator is adjusted to give a reference signal level approximately equivalent to the crosstalk level. The frequency deviation is adjusted to give a suitable number of peaks and troughs on the display of the combined waveform; the fault distance can then be obtained from the frequency spacing of peaks or troughs and the known phase characteristics of the cable.

The ultimate range of the method is limited by the high attenuation of the outer conductor path. Although this can be alleviated to some extent by the use of reduced test frequencies, a lower limit of about 1 MHz is dictated due to the decreasing separation between the inner and outer circuit "skin" currents at lower frequencies. So far, good results have been obtained

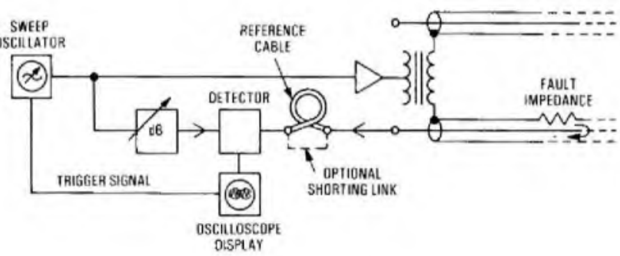


FIG. 7—Swept-frequency outer-injection crosstalk measurement technique

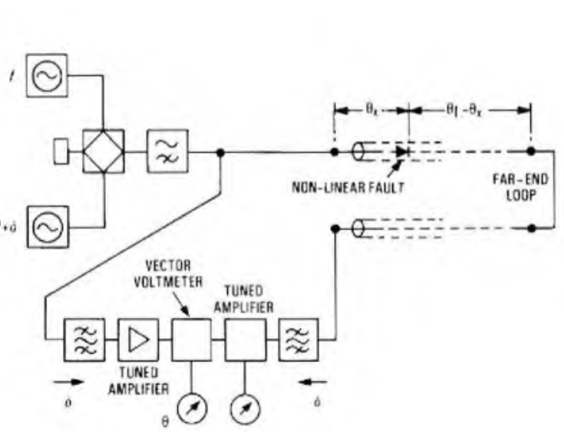


FIG. 8—Example of intermodulation technique for crosstalk measurement

at distances of 200 m on 1·2/4·4 mm cable, but the ultimate range of the technique has yet to be determined.

Intermodulation Techniques

Intermodulation techniques rely on the non-linear nature of the surface film at the fault to generate harmonic or intermodulation products. Previous experience suggests that high sensitivities should be possible, but little documented evidence can be found on the orders of magnitude of harmonic or intermodulation products generated, relative to the test signal or signals, for different types of fault.

A fault locator, based on the use of the second harmonic generated at the fault, has recently been introduced for field use. This has been successful in only a limited number of cases; in certain circumstances, the presence of faults has been detected, but location has not been possible. Consequently, a number of intermodulation techniques having higher potential sensitivity are being studied.

One of the possible arrangements is shown in Fig. 8. The test frequencies f and $f+\delta$ are applied to the coaxial pair under test, which is looped at the far end to another coaxial pair in the same cable. The presence of a non-linear fault results in propagation of modulation products in both directions. The difference frequency product is selected at each end of the loop, using high-gain narrow-band detectors, and the phase difference between the two signals, θ, is measured using a vector voltmeter.

If the distance to the fault is X, the distance to the far end is L and the respective phase changes are θ_X and θ_L, then

$$\theta = \theta_L + (\theta_L - \theta_X) - \theta_X. \qquad \ldots\ldots(1)$$

$$\therefore \quad \theta_X = \frac{2\theta_L - \theta}{2} \text{ or } X = \frac{2\theta_L - \theta}{2\theta_L} L. \qquad \ldots\ldots(2)$$

The loop phase change $2\theta_L$ can be determined either from the known length and phase change characteristic of the cable, or, by direct measurement using a reference non-linear fault (a diode) at the testing end.

To avoid ambiguity, the maximum phase change to be measured is arranged to be less than 2π rad. This can be achieved for all current repeater spacings by ensuring that the difference frequency is less than 100 kHz.

For most purposes, it should be possible to use two fixed test frequencies in the low megahertz region. However, where it might be necessary to locate multiple faults on the same coaxial pair, more complex equipment could be required and the use of amplitude and/or frequency discrimination could provide a solution. In the simpler case, using amplitude discrimination, reliance is placed on the likely differences between the transfer characteristics of separate faults and the square law dependence of the intermodulation signal. Thus the most serious fault would first be detected and cleared using low amplitude signals, thereby enabling less severe faults to be detected using higher amplitude signals.

Should the problem of multiple faults become significant a more powerful intermodulation technique using frequency discrimination offers a potential solution. In this technique, which can also be used with the swept-frequency crosstalk method, very high frequencies are used to detect nearby faults, and the frequency is progressively lowered for locating more distant faults. In such cases, it may be necessary to clear the nearby faults before the more distant ones can be located.

SYSTEM PERFORMANCE PREDICTIONS FOR 565 Mbit/s TRANSMISSION

General System Constraints

A summary of the general parameters of the 565 Mbit/s system studies for BPO applications is given in Table 1.

TABLE 1
Summary of 565 Mbit/s System Requirements

System input digit rate	565 Mbit/s	
Line code	4B3T	6B4T
Maximum section length (km)	1·1	1·1
Equalization, percentage raised cosine	75 or 100	
Nominal path loss (dB)	82·6	77·9

The choice of line code has been narrowed down to either 4B3T or 6B4T†, with either 100% or 75% raised cosine[20] equalization. In both cases, the nominal equalized path loss is 80 dB. This allows the minimum decision-point signal-to-noise ratio of 22·6 dB for an error rate of 10^{-11} to be achieved with a nominal 8 dB margin. The margin is necessary to allow for such effects as ageing, automatic gain control variations, equalization tolerance and eye closure resulting from echoes and inter-symbol interference.

The apportionment of the 8 dB margin to the various degrading phenomena is still a matter of debate. However, it has been suggested that 1 dB of the margin should be allocated for discrete echoes, while 0·4 dB, or perhaps even 1 dB, should be allowed for periodic echoes[21]. These figures are therefore adopted as a general guide in this analysis. The choice of these values is somewhat arbitary; other organizations are known to have adopted, or are still debating, different and somewhat less-pessimistic limits. In the following sections, a range of values for the echo margin and its influence on the choice of the line code are considered.

Accounting for Periodic Echoes

Considering the effect of periodic echoes alone, the effective signal-to-noise (S/N)[17] ratio can be written in the form:

$$S/N = \frac{S_O}{N_O}\left\{\frac{1}{1+\dfrac{S_O}{N_O}\dfrac{E}{S_O}}\right\}, \qquad \ldots\ldots(3)$$

where S_O is the received peak signal power,
N_O is the thermal noise power, and
E is the echo power due to periodic components.

Thus, if $\dfrac{S_O}{N_O} = 30$ dB, the limiting values of $\dfrac{E}{S_O}$ can be computed for a given allocation of the noise margin, Δ_p decibels, as given in Table 2.

TABLE 2
Example Noise Margin Figures

Noise Margin Δ_p(dB)	S/N(dB)	E/S_O(dB)
0·4	29·6	−40*
1·0	29	−36
1·5	28·5	−34
2·0	28	−32·3

* Early suggested value for UK system

The limiting values of $\dfrac{S_O}{E}$ can be related to the limiting RRL values, $R_L(f_0)$, by the following formula:

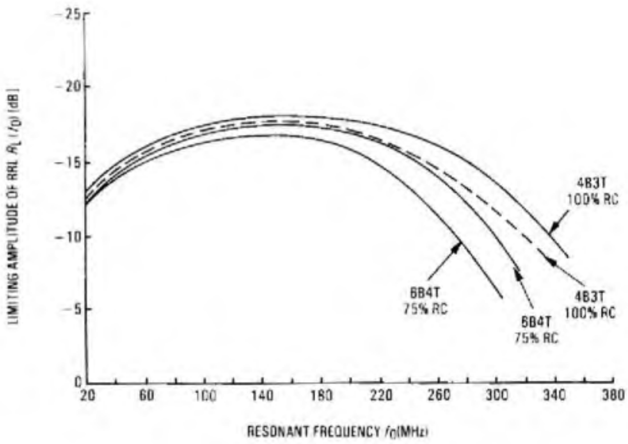
$$R_L(f_0) = \frac{E}{2S_O} + 5\log_{10}\left(\frac{Nf_M}{f_0}\right) - 15\log_{10}\alpha(f_0)L - 3\cdot62 - \frac{|R(f_0)|}{2}\ \text{dB}. \qquad \ldots\ldots(4)$$

where N is the number of periodic irregularities,
f_M is the system modulation rate,
f_0 is the resonant frequency of the RRL peak,
$\alpha(f_0)$ is the attenuation coefficient at resonance,
L is the length, and
$|R(f_0)|$ is the equalized amplitude at resonance.

A typical family of RRL profiles, for a noise margin of 0·4 dB, produced from equation (4), is given in Fig. 9.

Risk Estimates for Periodic Echoes

Selecting the RRL data appropriate to the bandwidth requirements of the 4B3T and 6B4T line codes gives the PDF shown in Fig. 10. Using this PDF in conjunction with the RRL profile of Fig. 9, and using an appropriate scaling of the results,



RC—raised cosine

FIG. 9—Profiles of return loss amplitude/limits for 565 Mbit/s transmission

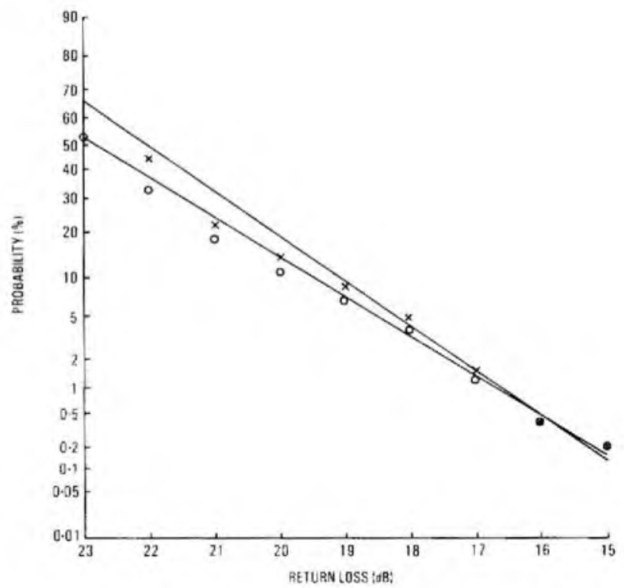


FIG. 10—Probability distribution function of return loss amplitude distribution

† nBmT line codes use m ternary signal elements to represent a group of n binary digits, thereby giving a line signal rate m/n times the input information rate

TABLE 3

Estimated Risk Figures for 565 Mbit/s Operation over 1·2/4·4 mm Coaxial Pairs with a Continuous and Well-Defined Periodic Structure throughout their Length

Ratio of periodic-echo-to-signal power E/S_0 (dB)	Margin against periodic echoes Δ (dB)	Percentage Risk of Unsatisfactory Operation at 565 Mbit/s	
		4B3T 100% raised cosine	6B4T 75% raised cosine
−40	0·4	15	3
−36	1·0	3	1
−34	1·5	1	0·3
−32·3	2·0	0·35	0·1

gives the risk figures for 565 Mbit/s operation shown in Table 3.

The figures in Table 3 represent the extreme case where a constant and severe level of periodic irregularity is maintained throughout the entire length of a repeater section. In practice, the usual situation in a typical cable section is that the occasional one or two pairs may exhibit severe periodic irregularity, but over short lengths only.

Coaxial pairs produced by a given manufacturer show significant correlation of RRL resonances in the frequency domain (that is, cables tend to exhibit unique signatures associated with the machinery used in their manufacture) and this has been allowed for in the calculations by using voltage addition. However, no significant amplitude correlation of RRL has been detected; thus, if the pairs are selected at random†, the total risk for a repeater section can be estimated by the following simplified relationship:

$$\Phi = \kappa\,\phi^{m}, \qquad \ldots\ldots(5)$$

where Φ is the total risk,

ϕ is the risk prescribed to individual coaxial pairs,

m is the number of cable lengths constituting a repeater section, and

κ is a correlation factor that weights the results to account for the total number of individual lengths per repeater section that violate the RRL limits.

Insufficient data is available to determine κ accurately, but the best estimate from the available information indicates an approximate value of unity. The value of m depends on installation practice (that is, the number of cascaded lengths in a repeater section), but normally falls in the range 2–7. Thus, for 1·2/4·4 mm repeater sections of nominal 1 km length, the risk of the periodic echo noise margin being exceeded is approximately bounded by the values:

$$\phi^2 \leqslant \Phi \leqslant \phi^7. \qquad \ldots\ldots(6)$$

Therefore, for the worst case of $\phi = 15\%$, $\Phi \leqslant 0{\cdot}15^2 \times 100\%$ and so $\Phi \leqslant 2{\cdot}3\%$ in all cases.

For the range of conditions being considered, the estimated risk of not exceeding the indicated margins, when selecting a single coaxial pair at random, is shown in Table 4.

The results in Table 4 relate to the risk associated with each coaxial pair, and since all coaxial pairs in the cable must be satisfactory, it is necessary to multiply the Table 4 risk factors for each pair by the number of coaxial pairs in the cable. Thus, for an 8-pair cable, using 6B4T code and allowing a 1 dB margin for periodic echoes, the risk would be $\leqslant 0{\cdot}08\%$.

† It should be noted that there is not only a marked variance in the RRL characteristics from different manufacturers' processes, but also a wide variance between cable pairs in any one cable made by a single manufacturer. Thus, in general, the configuration of a specific repeater section will involve a random combination of RRL characteristics, especially in terms of the relative amplitude

TABLE 4

Estimated Risk Figures for 565 Mbit/s Operation over the BPO Installed 1·2/4·4 mm Coaxial Pairs

Ratio of periodic-echo-to-signal power E/S_0 (dB)	Margin against periodic echoes Δ (dB)	Percentage Risk of Unsatisfactory Operation at 565 Mbit/s	
		4B3T 100% raised cosine	6B4T 75% raised cosine
−40	0·4	$\leqslant$2·3	$\leqslant$0·09
−36	1·0	$\leqslant$0·09	$\leqslant$0·01
−34	1·5	$\leqslant$0·01	$\leqslant 10^{-3}$
−32·3	2·0	$\leqslant 10^{-3}$	$\leqslant 10^{-4}$

Risk Estimate for Discrete Echoes

The results of the analysis of all available 2 ns return pulse-echo data are shown in Fig. 5(*b*), plotted as a PDF. These results do not include the effects of joints, tail cables and gas blocks because it is likely that these would have to be modified or changed for 565 Mbit/s transmission.

As a 1 dB allocation of noise margin represents a return pulse-echo loss of approximately 19 dB (assuming a pessimistic 100% forward reflection from the repeater termination), it is clear that the system margin is not even approached. Moreover, there is an added degree of pessimism associated with the results presented because the system is likely to use a 100% duty cycle launch signal, which in turn suggests a return pulse-echo test of about 2·4 ns for a 4B3T code and 2·7 ns for 6B4T as being more appropriate. The 2 ns results are therefore likely to give a pessimistic performance estimate.

CHOICE OF 565 Mbit/s SYSTEM

From the results presented, it is clear that discrete echoes within the cable do not present a problem. It is assumed that suitable high-frequency termination arrangements would be provided for 565 Mbit/s system and, therefore, no significant degradations should arise from this source.

The risk of unsatisfactory operation at 565 Mbit/s at nominal 1 km spacing on 1·2/4·4 mm cable arises almost entirely from periodic irregularities; as shown in Table 4, this covers a wide range, depending on the type of system. At present, the acceptable degree of risk is not known, but a possible target might be of the order of 0·1%. This would imply that, for every 1000 repeater sections equipped, one section would require cable length replacement.

Using the risk figures shown in Table 4, adjusted to allow for the increased risk arising from the number of coaxial pairs within the cable, appropriate parameters and margins for meeting the 0·1% risk criterion for most cable sizes would be as shown in Table 5.

TABLE 5

Parameters and Margins for 565 Mbit/s Operation on 1·2/4·4 mm Coaxial Cables

Maximum Repeater Spacing	1·1 km
Line Code	6B4T
Equalization	75% Raised Cosine
Margin for Periodic Irregularities	1 dB
Margin for Discrete Irregularities	1 dB

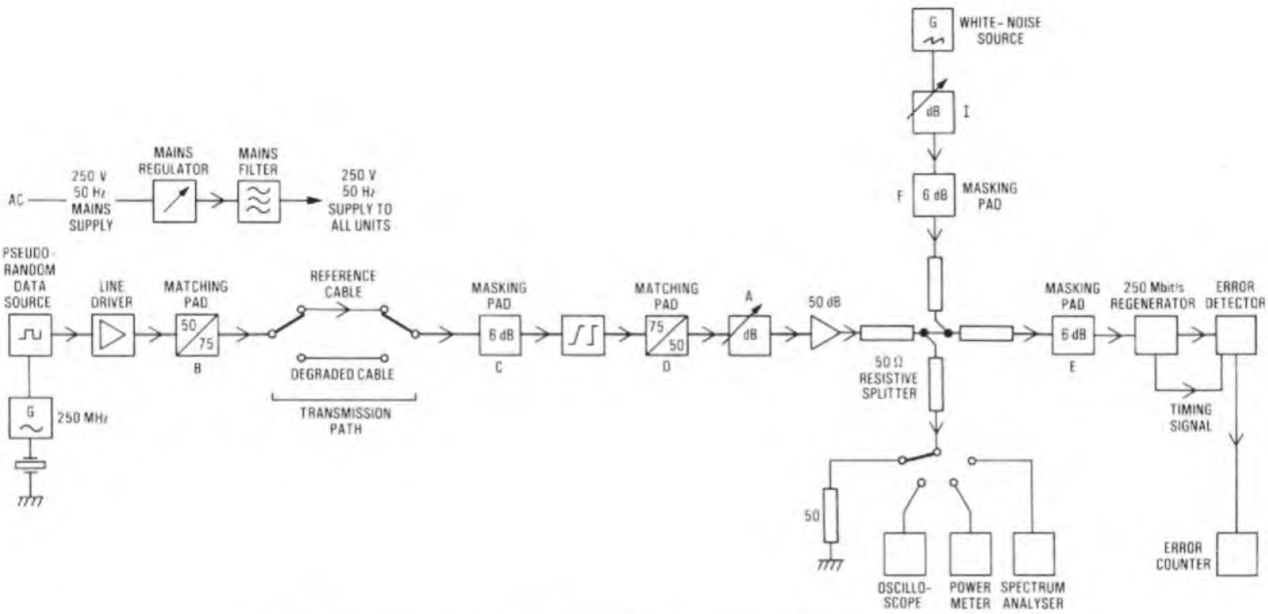


FIG. 11—Block diagram of 250 Mbit/s digital transmission measurement equipment

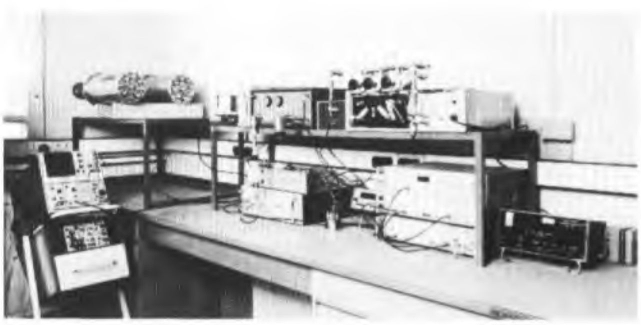


FIG. 12—250 Mbit/s transmission equipment

TRANSMISSION EXPERIMENTS

To verify the theoretical conclusions, digital transmission experiments were conducted. Unfortunately, test equipment was not available for use at 565 Mbit/s, and so suitably scaled experiments were conducted at both 140 Mbit/s and 250 Mbit/s using readily available repeaters and associated equipment.

The Test Equipment

An experimental test rig (see Figs. 11 and 12) was constructed to compare theoretical predictions with measured results. A binary system was used to simplify the problems associated with accounting for the different line codes being considered for very high bit-rate applications.

This equipment configuration enabled all significant echo phenomena to be investigated by direct simulation. Using the comparison method shown in Fig. 11, with precision attenuators, a stable noise source, a stabilized mains power supply, mains power filters and a temperature-controlled environment, a measurement uncertainty of less than ±0·025 dB with 95% confidence was achieved for all error probability measurements. This extreme accuracy was deemed to be necessary so that measured results (in the error probability range 10^{-2} to 10^{-10}) could be realistically extrapolated to an operational level where additional signal-to-noise ratio margin[21] would be allowed.

Cable Samples

The general quality of 1·2/4·4 mm cables is such that their degrading effect on error probability lies well outside an easily measurable range—even at 250 Mbit/s. To overcome this problem, a number of cable lengths were modified by deliberately deforming the cable structure in a planned manner to simulate the effects of severe structural periodicity and random discontinuities. To simulate extreme cases of random discontinuity (for example, arising from local damage or discontinuities at joints) discrete capacitors and/or resistors were introduced into the transmission path. These modified cable samples were also augmented by cable rejected during manufacture because of structural defects or damage, thereby allowing a comprehensive series of system conditions to be simulated.

System Simulation Results

The experiments performed, and the results produced, fall into three distinct categories concerned with the effects of:

(*a*) periodic echoes,
(*b*) discrete echoes, and
(*c*) combinations of periodic and discrete echoes.

Many different configurations were considered and the results compared with previously published signal-to-noise ratio predictions[17] of the form:

$$S/N = 10\log_{10}\frac{N_O}{S_O} + 20\log_{10}\left\{1 - \sum_i \left|\frac{\delta V_i}{V}\right|\right\} - 10\log_{10}\left\{1 + k\frac{S_O}{N_I}\right\}. \qquad \ldots\ldots(6)$$

where S_O is the signal power,

N_O is the thermal noise power,

N_I is the injected noise power,

k is a ratio of power relating the signal and periodic echoes, and

$\sum_i \left|\frac{\delta V_i}{V}\right|$ is the worst-case sumation of all discrete echoes.

In all cases, an acceptable degree of agreement was obtained between the measured and predicted results, as shown in the typical examples given in Figs. 13 and 14.

Additional experiments were also undertaken by another Research Department group[22]; these used the same cable models to perform scaled simulation with a 140 Mbit/s transmission system. These experiments used 4B3T and 6B4T coding equipment and, again, the results showed a good agreement between theory and practice.

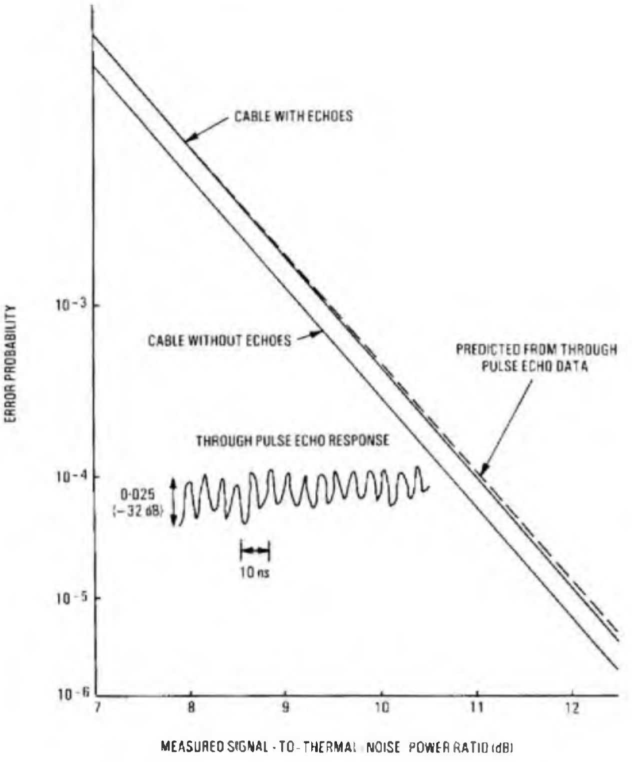


FIG. 13—System error probability performance for 1·2/4·4 mm coaxial cable with degraded periodic error characteristics

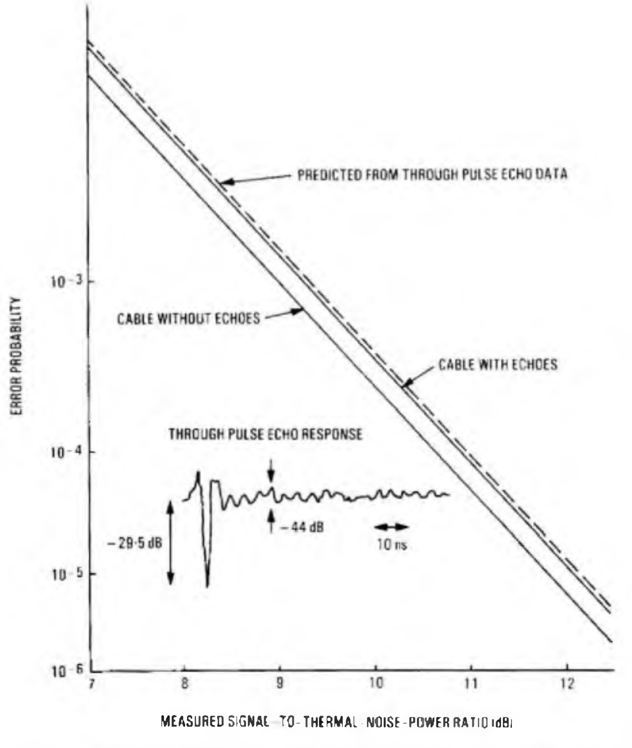


FIG. 14—Error probability performance resulting from combined discrete and periodic errors

PRE-DIGITALIZATION TESTING

As discussed previously, at the 120 Mbit/s and 140 Mbit/s rates, no problem arises in UK manufactured coaxial cables from lack of cable impedance uniformity. The purpose of testing installed repeater sections of cable, prior to the installation of such systems, is to ensure that there are no faults, either in the main cable or the associated terminations.

For 565 Mbit/s, or higher bit-rate operation, the cable quality is more marginal and it would be advisable to undertake transmission type tests on repeater sections intended for use at such bit rates. To meet this requirement, a system-oriented test method has been developed[17], which provides a direct measurement of the forward echo arising as a result of multiple reflections at points of impedance discontinuity. In this test, high-amplitude pulses are transmitted into the equalized repeater section and the received pulses are detected at the remote end using a signal-averaging, cross-correlation detector to obtain the required sensitivity.

A significant advantage of the technique is that the effects of both discrete and periodic echoes can be identified separately, and these should fall within pre-defined upper bounds. The high sensitivity obtained enables the test equipment to be reconfigured for equalized, return-pulse-echo and crosstalk measurements up to sensitivities of the order of 180 dB. Pulse attenuation and delay measurements can also be made.

The equipment described has been demonstrated in the field; it has proved to be suitable for checking repeater section lengths of cable for digital transmission over a wide range of bit rates and locating any portion of the cable that falls below the required transmission standards.

CONCLUSIONS

Theoretical and practical studies, based on comprehensive data obtained from Industry and BPO cable measurements, have shown that the BPO coaxial network can adequately support a wide range of digital transmission systems, including the currently installed 120 Mbit/s systems through to possible future 565 Mbit/s systems. The only slight impediment to the direct implementation of such systems is the presence of incipient faults, but these can be rectified prior to or during the change-over from FDM to digital operation and do not therefore constitute a fundamental limitation to transmission capability.

Assuming the reduced repeater spacings for higher bit rate systems are acceptable, the factor that determines the upper limit of operation of a practical cable network is the magnitude of the structural irregularities; in particular, those of a periodic nature. This article has demonstrated that operation at rates up to 565 Mbit/s is not seriously at risk because of any structural phenomena inherent in the installed 1·2/4·4 mm cable network, and this conclusion almost certainly applies equally to the 2·6/9·5 mm network. However, the choice of system parameters is influenced by the level and frequency of structural periodicities. Within the confines of the previously reported studies, it has been shown that 565 Mbit/s systems, using either 4B3T or 6B4T coding could be accommodated by the network with low risk and with acceptable system margins at half the repeater spacing of the 140 Mbit/s systems.

It is also clear from the studies that operation at rates higher than 565 Mbit/s would be feasible, but it is likely that specific routes would have to be selected to meet the system margin requirements. In particular, the high quality 60 MHz FDM cable routes should be ideally suited to operational rates in excess of 565 Mbit/s.

A demonstration of a 565 Mbit/s DLS incorporating

(*a*) 4 × 140 Mbit/s muldex,

(*b*) 3 dependent regenerators,

(*c*) in-service supervisory system, and

(*d*) power feeding at ± 500 V, 350 mA

is to take place at the BPO Research Centre at Martlesham in the week beginning 20th October 1980.

The system will be routed on 1·2/4·4 mm cable with repeaters spaced at 1 km (approximately) and will use a 6B4T line code. It is thought to be the first complete system of its type to be demonstrated anywhere in the world.

The eventual use of any part of the coaxial network at rates greater than 140 Mbit/s will obviously depend on the relative costs of converting an existing coaxial route compared with installing a new optical fibre system. Time scales will thus figure largely in such decisions.

In closing, it is thought that the soundness of the present coaxial cable designs, which have already seen many years of service, should be acknowledged, bearing in mind that they have proved capable of supporting digital transmission over bandwidths at least two orders of magnitude greater than originally intended.

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Book Review

Mathematics Level II. J. Morris. Van Nostrand Reinhold. xii + 119 pp. 143 ills. Cloth cover: £8·00; paperback: £3·50.

Mathematics Level III. J Morris. Van Nostrand Reinhold. ix + 94 pp. 95 ills. Cloth cover: £6·50; paperback: £3·00.

Mathematics Level II has been written to cover the teaching objectives laid down by the Technician Education Council (TEC) for the Mathematics half units U75/012, U75/038 and U75/039. The first part of the book deals with U75/012 and the latter part, because of the relationship between the topics, deals jointly with U75/038 and U75/039. A student taking Mathematics Level II will study the first half unit and one of the other two half units, depending on his need to study applications and concepts or the analytical approach. A most useful table is given at the front of the book to guide him to the parts of the text that his course of study demands.

Mathematics Level III has been written to cover the teaching objectives laid down by TEC for the Mathematics unit U75/040, which forms part of the majority of standard programmes and which will be taken by students who have successfully completed the level II half unit U75/039. For the series of books, the publishers have chosen a two-column page layout which gives a line too short for many mathematical expressions; this causes them to be cramped or to run onto the next line. Where tables are required, such as in the graph and statistic sections, they are placed at the foot and/or the head of the page. This may be good aesthetically, but educationally it is unsatisfactory, since the search for a table often interrupts the train of learning.

Both books are split into several sections, closely following the topic areas of the TEC syllabi, with each of the sections being further split so as to deal with all the unit behavioural objectives. While all the teaching objectives are covered, in my opinion the treatment of some subject areas is insufficient; for example, integration (level II) takes only two pages. Each section contains a number of worked examples, but both texts would have benefited if a larger number of more varied examples had been incorporated in them and if those that were included had had more words of explanation given to the working steps involved. The parts within each section all contain a large number and variety of unworked examples which help the student to assimilate the knowledge and also to assess his own performance.

Far more attention should have been given to the artwork. The basic idea of the figures is good, but in many cases the dimensioning is incorrect and this causes the figures to be misleading. The shapes of many of the sine waves are also inaccurate.

Both books end with several pages of multiple-choice questions, with their answers, which are most useful since TEC lay down that this type of question should form part of the assessment plan; practice in answering examination-type questions is to be recommended.

To sum up, I feel that Mathematics Level II and Level III could be usefully employed in a classroom as supplements to lectures or as concise revision courses; but I would not advocate their use in a self-teaching situation.

R. SUTTON

Character Coding for Text Communication

Part 1–Background to Character Coding

A. J. WHALL, B.SC., M.I.E.E.†

UDC 681.3.04:621.397.12

There is a rapidly growing worldwide interest in electronic mail and information retrieval systems. The development of appropriate standards for these systems and services concerns many national and international committees. This article, in 2 parts, describes the background to character coding work within the International Standards Organization and the CCITT (part 1) and the practical coding schemes developed (part 2). The article concentrates on the coding of graphic characters in order to illustrate the techniques. Coded character sets for text communication for the new range of services currently in the course of development are described.*

INTRODUCTION

What is a character set? Where does it fit into the overall picture of text communication? Applying a simple hierarchical structure to this work enables character coding to be seen in the context of the overall range of techniques available. Part of such a hierarchy is illustrated in Fig. 1. Other models of general text communication may be used; the one shown is not definitive and is merely used to illustrate a relationship between the various services and techniques.

Two major worldwide text communication services are in the course of detailed definition within the various standardization committees; these are Videotex and Teletex. Videotex is the name provisionally adopted within the CCITT* for public-network-based information retrieval systems using suitably equipped television receivers. The British Post Office (BPO) Prestel service is the world's first Videotex service. Teletex is the service currently being defined by the CCITT which will permit worldwide communication of business correspondence between suitable terminals, in such a way that the recipient of the information will be presented with a document which is identical in content, layout and format with that transmitted by the sender.

In the future, the development of system capabilities will lead to an integration of advanced picture-drawing and photographic capabilities within systems and terminal equipment but, for the present, the use of coded character sets for the communication of text is a basic requirement for systems; the development of suitable international standards is a prerequisite to enable rapid development of the equipment to provide these services on an international scale. Full descriptions of the various schemes are given in the appropriate standards.

† Network Strategy Department, Telecommunications Headquarters

* CCITT—International Telegraph and Telephone Consultative Committee

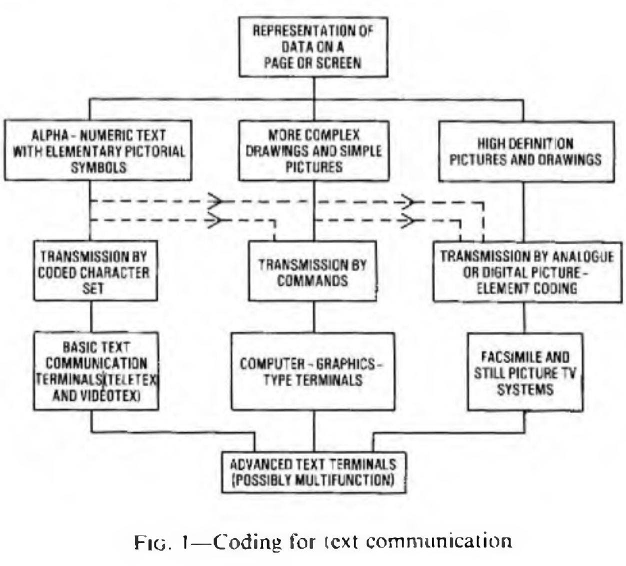


FIG. 1—Coding for text communication

HISTORICAL BACKGROUND

The first international standard character code for text communication was probably the International Telegraph Alphabet No. 2 (ITA2)[1], which has been in existence for some 40 years. This character set has been widely used on private telegraph circuits throughout the world and, more significantly, it is the code used for the international Telex service.

In the early years of computer communications, ITA2 was the only standardized code available, but it was obvious that an extended code was necessary to cater for the wider repertoire of characters necessary for data communications. Various methods of extending the 5-unit ITA2 code were considered, relying in general on the use of multiple figure-shift and letter-shift control sequences. This philosophy was eventually abandoned and coding based on 6 bit/character was briefly considered before it, too, was rejected. The American Standard Code for Information Exchange (ASCII) was proposed in 1962, and subsequently became the basis of work in the international standard committees. With some minor changes, the ASCII is embodied in the CCITT Recommendation V3 as the International Alphabet No. 5 (IA5)[2] and in the International Standards Organization (ISO) Standard ISO 646 as the international reference version (IRV). Recommendation V3 and standard ISO 646 are identical in technical content although minor variations of wording exist.

For over a decade the IA5 has served the needs of data users. However, the advent of low-cost digital circuitry and, in particular the microprocessor, has led to the development of terminal equipment with ever increasing sophistication. Whereas simple electromechanical printers have, in the past, been limited to presenting only that range of characters contained in their set of print elements (or possibly a limited range of composed characters; for example, some accented characters) modern microprocessor-controlled terminals can, by the use of incremental movements of the print head, image satisfactorily a much greater range of characters, utilizing the same basic selection of printing elements.

In recent years, postal services throughout the world have been in apparent decline. At the same time, the quest for greater office efficiency has led to growing awareness of the potential benefits of electronic mail and information retrieval services. This coming together of user demand for services and the technological means to satisfy that demand was recognized by the CCITT when, in 1977, it began its study of the Teletex service, followed in May 1978 by the adoption of questions relating to Videotex. At the same time, a technical committee of the ISO adopted a work programme to develop a general coded character set for all text-communication applications, including Teletex and Videotex. This standard is still being considered by the relevant ISO technical committee; when it is ratified it will be published as ISO 6937. For the present, the CCITT has developed specific codes for each of its regulated services, Teletex and Videotex. Further work may include a more general-purpose standard along the lines of ISO 6937.

SHORTCOMING OF RECOMMENDATION V3 FOR TEXT COMMUNICATION

Recommendation V3 consists of a 7-bit code table arranged as a rectangular array of 8 columns and 16 rows. Columns 0 and 1 are reserved for control characters, and columns 2–7 are available for graphic characters. The recommendation defines 2 versions of the code table, a basic table and the international reference version, which is known as *IA5*. The basic table has certain code-table positions left blank, and these may be allocated nationally or by individual equipment implementors, who choose the basic table as their starting point.

The IA5 (see Fig. 2) is a fully defined table allowing no variations and it is intended to be used for all international interchange and for national and application-oriented use when there is no special requirement for different characters. Herein lay the paradox; whereas the ability to use a national version of the basic table has led to widespread equipment implementation having a large degree of compatibility, the national differences have prevented fully acceptable international interworking. The IA5 did permit interworking but could, basically, only cater for English and possibly French. Many Latin-alphabet-based languages, in particular those of eastern Europe, require many more special letters and symbols.

				b_7	0	0	0	0	1	1	1	1
				b_6	0	0	1	1	0	0	1	1
				b_5	0	1	0	1	0	1	0	1
b_4	b_3	b_2	b_1		0	1	2	3	4	5	6	7
0	0	0	0	0			SPACE	0	@ ①	P	` ①	p
0	0	0	1	1			!	1	A	Q	a	q
0	0	1	0	2			"	2	B	R	b	r
0	0	1	1	3			# ①	3	C	S	c	s
0	1	0	0	4			¤ ①	4	D	T	d	t
0	1	0	1	5			%	5	E	U	e	u
0	1	1	0	6			&	6	F	V	f	v
0	1	1	1	7			'	7	G	W	g	w
1	0	0	0	8			(	8	H	X	h	x
1	0	0	1	9			)	9	I	Y	i	y
1	0	1	0	10			*	:	J	Z	j	z
1	0	1	1	11			+	;	K	[①	k	{ ①
1	1	0	0	12			,	<	L	\ ①	l	| ①
1	1	0	1	13			−	=	M	] ①	m	} ①
1	1	1	0	14			.	>	N	^ ①	n	‾ ①
1	1	1	1	15			/	?	O	_	o	DELETE

① In the basic table of recommendation V3 these may have alternative meanings

Note: Shaded columns are used for controls

FIG. 2—The graphic part of International Alphabet No. 5

CODE EXTENSION

In order to extend the usefulness of the ISO 7-bit code, a companion standard to ISO 646 was published as ISO 2022. This standard defines methods of code extension for use with 7-bit coded character sets. The code extension principles in ISO 2022 are based on the use of additional control characters, either alone or in defined sequences, to extend the range of both graphic characters and control functions. All code extension work is based on the principles defined in ISO 2022

As defined in Recommendation V3, the IA5 consists of a set of 32 control characters plus a set of 94 graphic symbols together with *space* coded as column 2, row 0 (2/0) and *delete* coded 7/15. The control characters *shift out* (*SO*), *shift in* (*SI*) and *escape* (*ESC*) are included in the set of 32 controls. These control characters are used to permit the representation of alternative sets of control functions or graphic characters in a 7-bit environment. This general structure of code extension is illustrated in Fig. 3.

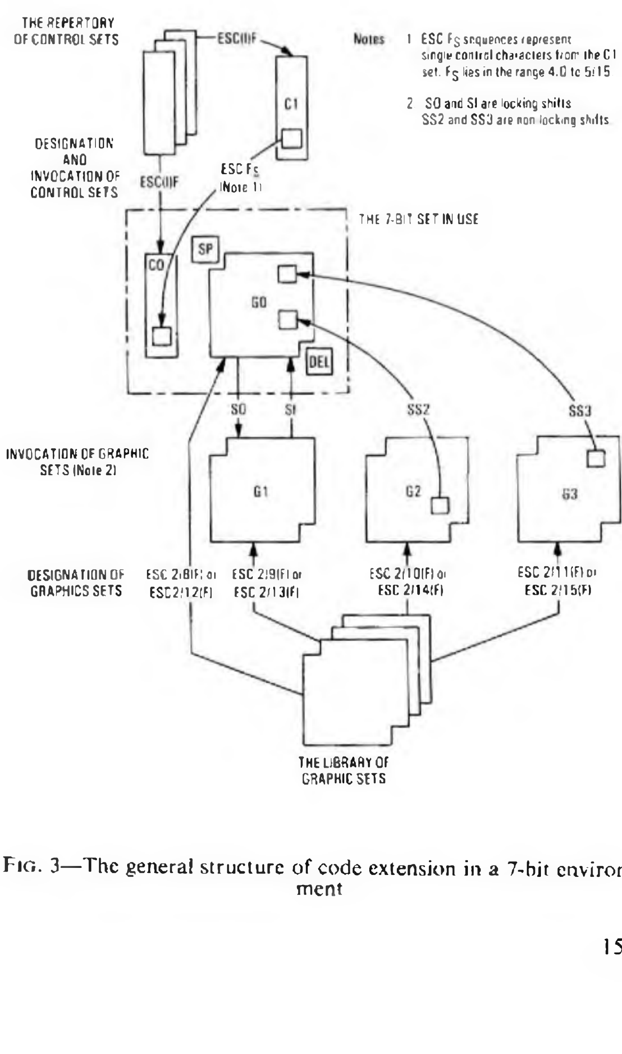


FIG. 3—The general structure of code extension in a 7-bit environment

To remain compatible with Recommendation V3, certain rules must be obeyed when defining these alternative sets:

(*a*) *SO*, *SI* and *ESC* must be contained within the alternative control set,

(*b*) the bit combinations corresponding to *space* and *delete* must not be used for other graphic characters, and

(*c*) the 10 transmission controls defined in V3 must not be used for other purposes.

Compatibility with Recommendation V3 is important to ensure that new systems using the extended sets remain compatible with the large amount of equipment based on the older standard.

Referring to Fig. 3, the 7-bit set in use comprises the C0 and G0 sets of control functions and graphic characters respectively.

Alternative sets of characters are called C1 and G1 respectively. Thus, a terminal may have within its store a library of 2 or more sets of 32 control functions and 2 or more sets of 94 graphic characters. The C0 and G0 sets represent the 7-bit set in use; that is, they are the normally available sets. If it is required to change to the alternative (G1) graphic set, then this is *invoked* by means of the control *SO*, which causes the bit combinations following to be interpreted as characters from the G1 set until the occurence of an *SI* character which restores the G0 set. If still more graphic sets are required (for example, it might be necessary to have available within a terminal English, Russian (cyrillic alphabet) and special scientific characters) then the process of *designation* is used.

From the library of sets of graphic characters stored within the terminal, a set is designated as G0 or G1 by means of a sequence of control characters of the form *ESC* (*I*) (*F*), where (*I*) and (*F*) are the intermediate and final characters of the sequence and are assigned by the ISO, which maintains a registration authority for this purpose. In practice, implementors submit their sets of symbols or control functions to the ISO; providing the set complies with the registration requirements, a designation sequence is allocated with (*I*) indicating whether the set is to be used as G0, G1, G2 or G3 and (*F*) being a unique identifier for that set of symbols. The ISO-registered designation is then available for use internationally. Similar principles of designation apply to sets of control functions. At the present time, about 20–30 graphic character sets have been registered with the ISO, or are in course of being scrutinized by the registration authority. These sets include the Japanese Kanji set of ideographs consisting of several thousand symbols and which is represented by 2-byte combinations.

Thus, in broad terms, invocation is the method of directly calling a set of characters which has been previously designated for use as G0, G1, etc. Invocation allows characters to be coded for transmission on a character-by-character basis from two or more different sets, whereas designation would typically be used on call set-up to indicate which sets are to be invoked during the call. In essence, code extension can take four forms:

(*a*) code extension by substitution,

(*b*) code extension by composition,

(*c*) direct coding, or

(*d*) 8-bit coding.

In practical coding schemes, mixtures of these techniques tend to be used.

CODE EXTENSION BY SUBSTITUTION

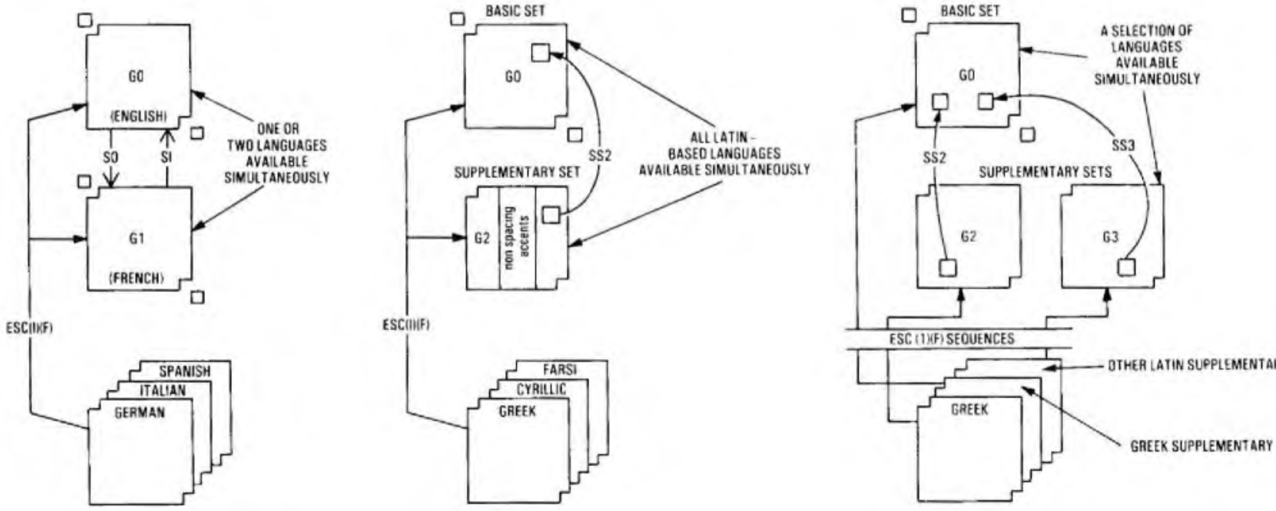
By defining the graphic sets of 94 symbols to correspond to, say, an interchangeable set of printing elements, then the technique of code extension by substitution can be applied to simple equipment without the facility of incremental movement. Typical of equipment which could be used with this type of coding scheme are "golf ball" typewriters having 96 printing elements on each print ball which may be arranged to correspond to a particular registered set. A stock of print balls thus allows many languages and type-styles to be produced on one machine.

The major disadvantages of extension by substitution are

(*a*) a particular symbol may have different coded representation in different registered sets; thus, equipment based on character generators (for example, matrix printers) would need more complex transcoding algorithms, for conversion between the line code and the machine code, and

(*b*) certain languages would require more than one set of characters and, therefore, implementation and use in these cases would be more difficult, particularly in automatic systems.

Fig. 4(*a*) illustrates code extension by substitution.



(*a*) Code extension by substitution

(*b*) Composition coding

(*c*) Direct coding

Note: Greek, Cyrillic, etc sets may be designated as G0/G2 pairs

FIG. 4—Illustration of code extension schemes in a 7-bit environment

CODE EXTENSION BY COMPOSITION

Most accented letters occur infrequently in text, typically 5–10% for western European languages and 10–15% for certain eastern European languages. Because of this, a code extension technique, whereby an accented letter is transmitted as a sequence of bit-combinations representing the basic letter and the accent mark separately, can be used with little overall effect on the transmission efficiency. The IA5 contains 6 symbols which may be used together with *backspace* (*BS*) to represent diacritical marks. However, it is generally agreed that, for text communication, about 14 diacritical marks are necessary. Furthermore, when the special requirements for transliteration of non-Latin alphabet languages are considered, this number increases considerably. There is, therefore, a clear need for more than a single code table to enable these characters to be catered for. A recent addition to standard ISO 2022 makes provision for 2 non-locking shift control characters called *single shift 2* (*SS2*) and *single shift 3* (*SS3*). The occurence of one of these characters causes the single bit-combination which follows to represent a character from a G2 or a G3 set of graphic characters respectively. By coding the diacritical marks as elements of a G2 set it is possible to transmit an accented letter. For example, é (e with acute accent) as

6/5 0/8 1/9 5/2 or 1/2 5/2 0/8 6/5

e *BS* *SS2* ′ *SS2* ′ *BS* e

In the interests of transmission economy, the *BS* may be implied; that is, the diacritical mark can be coded as a non-spacing character (analogous to the dead keys on many office typewriters). Code extension by composition has the benefit of economy of usage of coding resources at the expense of some loss of transmission efficiency. The method is, of course, only useful for dealing with accented letters; other alphabetic symbols would require the appropriate coding resources to be made available, which could defeat the object of using the composition method. In part 2 of this article, however, it will be seen that taking account of the Latin-alphabet-based languages results in a repertoire of characters which is amenable to the composition method of coding. Because of this, composition coding has been chosen as the basis of code extension for the new text communication standards.

Composition coding, although economic in the utilization of coding resources, is not the most efficient scheme in terms of transmission efficiency. From the point of view of terminal implementation it suits terminals with a backspace and overprinting capability, but it is less useful for raster-scan screen-based terminals. In the latter case, the transcoding algorithm needs to be aware of many non-valid code combinations and, also with this type of terminal, it is usual to store the complete character shape to be displayed. Therefore, any transcoding is an undesirable overhead. Fig. 4(*b*) illustrates composition coding.

DIRECT CODING

Because Videotex is essentially a screen-based-terminal service, proposals were made by the BPO that the so-called *direct coding* method should be considered as the basis of the coding scheme for text communication. The term direct coding is used to distinguish this method from the substitution method; in both cases, the displayed character is represented on the transmission line by a single bit-combination. With the proposal, 3 simultaneous sets of graphic characters G0, G2 and G3 would be designated for simultaneous use; each graphic character would be coded with a single bit-combination. (Characters from G2 and G3 sets being invoked by means of *SS2* and *SS3*) This would give inherent transmission efficiency and would simplify terminal design for both matrix printers and, more especially, for Videotex-type terminals; in particular, it eases compatibility between Videotex and British-type (video synchronous) broadcast Teletext systems. Although direct coding is acknowledged by most workers to be simple to implement in practically useful international text-communication systems, it was not chosen as the basis for the standards because it apparently required more than G0, G2 and G3 sets to cater for all Latin-alphabet languages simultaneously. It was also claimed that the composition method of coding was more flexible to cater for future expansions.

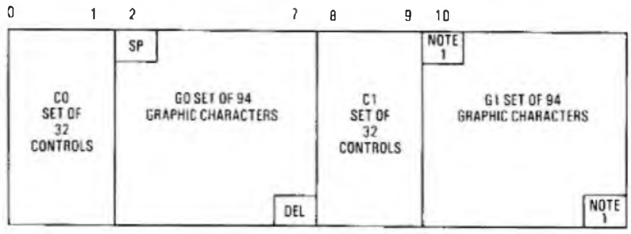
Direct coding also has the disadvantage that the utilization of coding resources is less efficient than the composition method (but is more efficient than the substitution method). Also, for simple terminals the backspace and overprint facility was felt to be of some importance for services other than Videotex. Fig. 4(*c*) illustrates direct coding.

8-BIT CODING

The use of a 7-bit code structure for IA5 together with synchronous transmission techniques results in an 8-bit code structure on the transmission line; that is, 7 bits plus a parity check bit.

Most computers, microprocessors and memory devices are organized on the basis of an 8-bit structure. Furthermore, on modern data transmission networks the trend is towards synchronous transmission techniques using frame-structured data, together with cyclic redundancy error-checking mechanisms rather than the simple parity check which has been the usual method with the 7-bit code. The modern trend, therefore, is towards the transmission of 8-bit data bytes and towards an 8-bit code for text communication; 8-bit coding enables 64 control functions together with 188 graphic characters, to be immediately available, and is therefore an attractive candidate as a coding scheme. Although described here as if it were an alternative to the other coding schemes, 8-bit coding is in fact capable of being implemented together with either composition, substitution or direct coding schemes. The capacity of 8-bit coding schemes is such that they can cater for some applications (for example, Teletex at a basic level) without recourse to further code extension.

At the present time, to ease the introduction of new systems, the ISO and the CCITT are jointly discussing the most appropriate means of providing for code extension in the 8-bit environment in order to maximize the inherent flexibility of the 8-bit structure, while keeping the transcoding algorithms for 7-bit to 8-bit interworking as simple as possible. The structure of the 8-bit character code is shown in Fig. 5.



Note 1: Character locations reserved for compatibility with G0 set

FIG. 5—Structure of the 8-bit code

To be continued

References

[1] CCITT Recommendation F1, International Telegraph Alphabet No. 2, Orange Book, Vol. II, 3.

[2] CCITT Recommendation V3, International Alphabet No. 5, Orange Book, Vol. III, 1.

System X: Subsystems

Part 3—Processor Utility Subsystem

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UDC 621.395. 34: 681.31

System X exchanges use stored-program control for major operational functions. This article covers a specialized processor subsystem that gives the required security levels and provides the storage and processing power required by the System X exchange software subsystems.

INTRODUCTION

System X is designed to be modular and is capable of incorporating future advances in technology, system design, software structure, high-level languages and other design features should there be advantage to do so.

The exchanges designed for the System X family of exchanges use stored-program control. The digital main network switching centre (DMNSC) has been described in this *Journal**; the DMNSC applications programs are processed by a processor utility (PU) subsystem.

SYSTEM X EXCHANGE SOFTWARE STRUCTURE

The computer programs (software) are divided into a number of functional subsystems: typical software subsystems are the call processing subsystem (CPS), the maintenance control subsystem (MCS) and the management statistical subsystem (MSS); the digital switching subsystem (DSS) and the analogue line terminating subsystem (ALTS) are typical of the hardware subsystems which incorporate software handlers. The same software structures are used for software and hardware subsystems, and the PU provides the greater part of the processing power required; microprocessors provide the balance. The operating system (OS), tied to the particular processor utility, is separate from the applications programs (APs) and distributes the computing resources to them. The software programs and data resides in the storage (memory) provided with the PU.

The software in each subsystem is divided up into one or more processes, each of which is made up of modules. Each process performs a particular function. A process comprises programs that control the processing performed by the PU on data held in store, some of which may be dedicated and some shared. The process is activated by information arriving from other APs or the OS. The interfaces between processes is rigidly defined, as are the structures of the processes.

PROCESSOR HARDWARE CONFIGURATION

The PU architecture provides for multi-processing with $n + m$ CPUs having access to $p + q$ store blocks: the values of m and q will be decided by the security needs and the values of p and n by the processing capacity required.

Processes

Processes are allocated processing power by that part of the PU software 'operating system' (OS) which controls the way in which the PU can function and which schedules the processes to the central processing units (CPUs). A number of CPUs are available to provide processing power: a process may be handled by any CPU. That part of the OS that schedules the use of a CPU runs when the currently running process requires no further activity or a higher priority process needs a CPU. The OS also runs to deal with interrupts and fault conditions. An interrupt is triggered by particular peripheral devices when they require attention: in this case, the CPU interrupted is that having the lowest priority of process running.

When a running process is interrupted, the register contents for the process are saved in a process descriptor. The process can therefore be retrieved and run later when processing power becomes available.

Individual processes may not be run on more than one CPU at a time. If, for performance purposes, it is required that a process should be running on more than one CPU then the process will be replicated. Replications do not all have the same priorities, but they usually have a band of adjacent priority levels.

Process Security

Each process is a software security unit required to be confined to storage and input/output (I/O) hardware allocated to it. These process boundaries are maintained by various hardware and software checks in the operating system.

The software is designed so that the malfunction of a software module does not propagate to other modules. To this end, the aim of the application program data structures is that there should be a very limited amount of storage shared by different processes.

A process is therefore a unit of software that is scheduled to run on a CPU; a process comprises a grouping of software modules, and it has a unique scheduling priority and its own read/write working storage. A process performs a particular operation on all the calls in progress at the appropriate stage of the call. Whenever a process is run it executes the basic code for each call. Since the handling of a call requires a large number of functions, the call must pass from one process to another. Data transfers from one process to another is achieved by means of messages (*tasks*). The handling of these message transfers is performed by the process allocator (PA). The transfers take a finite time and the software is partitioned into processes taking account of the message transfer requirements. The process boundaries are organized to minimize the message or task traffic.

In each exchange the hardware will be provided with the necessary support software. The hardware will be dimensioned to meet the exchange requirements in respect of storage and processing power. The support software will be provided with data appropriate to the exchange.

The hardware configurations of the PU are shown in Fig. 1, and the location of the processor utilities within the System X exchange software modules is shown in Fig. 2.

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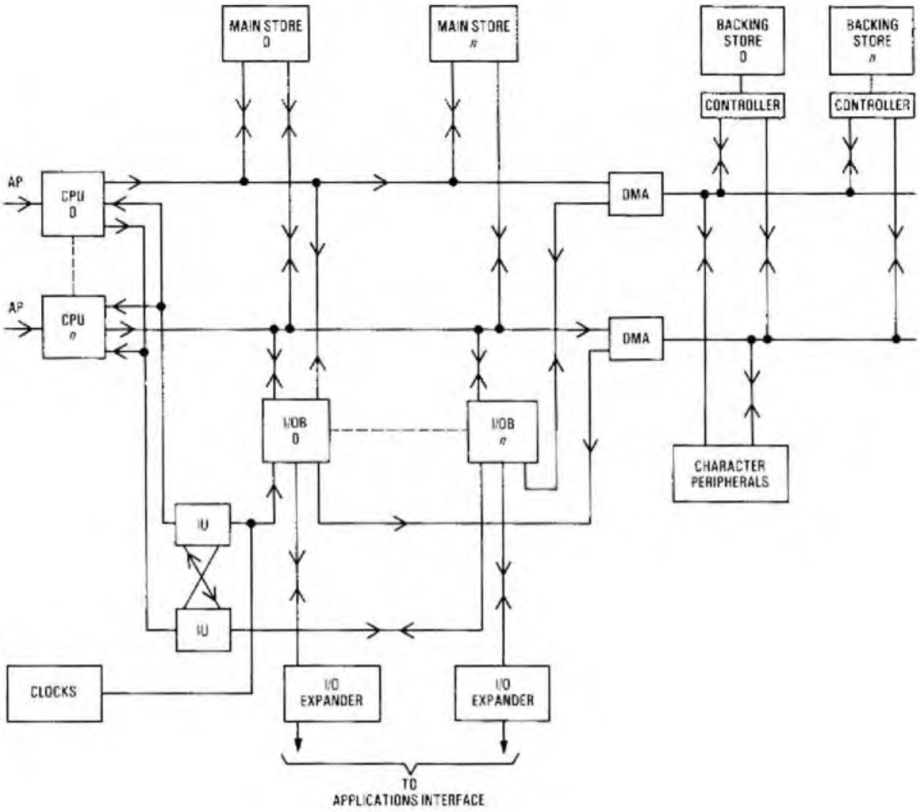
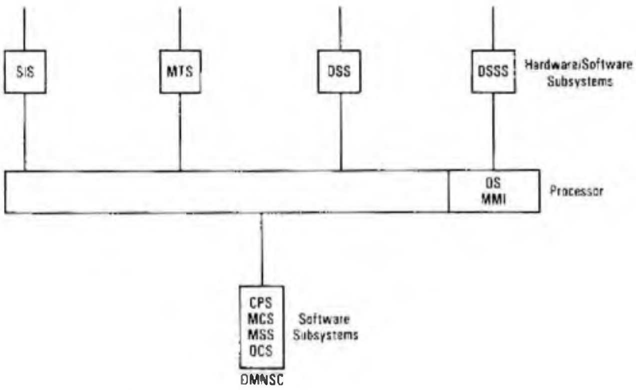
† System X Development Department, Telecommunications Headquarters.

* VANNER, N. J. Architecture of System X. Part 2—The Digital Trunk Exchange. *POEEJ*, Vol. 72, p. 142, Oct. 1979.



CPU: Central processing unit
DMA: Direct memory access
I/OB: Input/output block
IU: Interrupt unit

Fig. 1—Block diagram of the PU hardware



CPS: Call processing subsystem
DMNSC: Digital main network switching centre
DSS: Digital switching subsystem
DSSS: Digital subscribers switching subsystem
MCS: Maintenance control subsystem
MMI: Man-machine interface
MSS: Management statistics subsystem
MTS: Message transmission subsystem
OCS: Overload control subsystem
OS: Operating system
SIS: Signalling interworking subsystem

Fig. 2—The PU interface to subsystems

HARDWARE MODULES

The hardware modules comprise CPUs, shared stores, input/output blocks, direct memory access (DMA) units, peripheral controllers, backing stores, peripherals, magnetic-tape, cartridge units, visual display units (VDUs), teletype, maintenance console, clock timing modules, interrupt units and I/O block expanders.

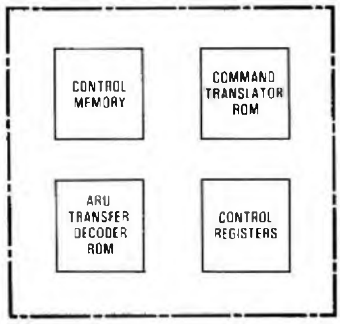
The hardware for each of these processor utility subsystems follows the System X equipment practice and hardware design rules. The hardware is mounted on standard System X equipment racks.

BASIC FAULT-RECOVERY MECHANISM

Hardware is assembled in the PU in discrete units, each of which can function as an entity. This form of assembly enables rapid location of, and recovery from, fault conditions. The PU software is able to respond to an indication arising from the fault-detection mechanisms and to remove complete functional units from service while distributing the load over the remaining equipment. The software is able to carry out checks on the equipment in which a fault condition has been detected. If the fault is of a transient nature and the equipment is tested and found to be satisfactory, it will be returned to service and a record made of the detected fault condition. If the fault condition persists, the faulty equipment will be reported to the maintenance control point so that remedial action can be taken. The PU is also equipped with software that enables faulty items within the functional entity to be identified.

PROCESSOR-UTILITY MICROPROGRAM

The technique of microprogramming is used extensively within the PU; a brief description of the microprogram is now given in support of the hardware description. The basic function of the microprogram is to provide the control for the execution of the machine instructions. The machine command-words are translated into control fields, which set up data paths in



ARU: Arithmetic unit
ROM: Read-only memory

FIG. 3—Basic microprogram components

the processor. Instructions require one or more commands and result in the transfer of data between registers. The basic microprogram components are shown in Fig. 3.

BASIC OPERATION

The basic operation of the microprogramming process is initiated by a command-word, which is transferred to a clock buffer store. The command word specifies the instruction to be performed and the register input and output data to be derived. Instructions may consist of multiple transfers with the input and output data being generated by the microprograms. The instructions address the command translator which, via an output field, determines a unique initial entry point for the instruction in the control memory.

A translator output will, in some circumstances, be used to address the arithmetic unit (ARU) and transfer decode read-only memory (ROM). This transfer field may also have received information from the control memory which may be used to derive arithmetic unit control data.

Signals are also produced to indicate the ARU functions and the output highway's address, message-length indicators, *next* instruction, *fetch*, etc. The appropriate registers operate at a rate determined by the microprogram clock.

Fault detection is provided and parity checks are carried out on the output fields on the ROM. A highway is provided to monitor all toggles and registers. Each CPU has access to private and shared store.

Error-control mechanisms are provided on the data busses between the CPUs and the stores. Information for use by the diagnostic system is generated as appropriate. Special facilities are provided to allow for automatic testing of a CPU suspected of being faulty.

CENTRAL PROCESSING UNIT

The CPU contains the conventional items required with a computer. The application of a CPU as part of a stored-program controller within a telephone exchange requires that its register set is particularly powerful; examples of which are index, program, status and history registers.

CPU hardware faults are usually found by parity failure and time outs, although other detection mechanisms are provided. When a fault is detected, the CPU timing system is stopped and its access port (AP) opened. This latter allows a failed CPU to be tested by those CPUs still in service.

STORAGE

The main store is constructed using 16 kbit or 64 kbit metal-oxide semiconductor (MOS) RAM technology. A backing store is provided as part of the multi-level storage provided with the virtual memory system. The backing store may consist of a magnetic-disc store designed for very high reliability and of the 'fixed-head per track' type or may use magnetic-bubble-storage technology. The interface between the backing store and the PU elements is the direct memory access (DMA) unit; a controller is situated between the backing store and DMA.

Data is transferred to and from the backing store via a balanced line using line driver/receivers. This arrangement gives some flexibility in siting the backing store in the rack.

The task system, the usual mechanism for passing control information within the PU, is used to indicate the address of the data required and any other relevant information. A head-of-queue pointer is used to indicate the first task linked to the list queue. This task in turn points to subsequent tasks. Both head-of-queue and link addresses are virtual addresses. The controller contains a microprogram which exercises all the control required for the logic elements interfacing to the backing store and the DMA. A comprehensive range of failure detection mechanisms is provided; each has self-test and self-healing features. Normal access to the backing store for maintenance purposes is via the maintenance monitor.

OUTLINE OF THE DMA SYSTEM FUNCTION

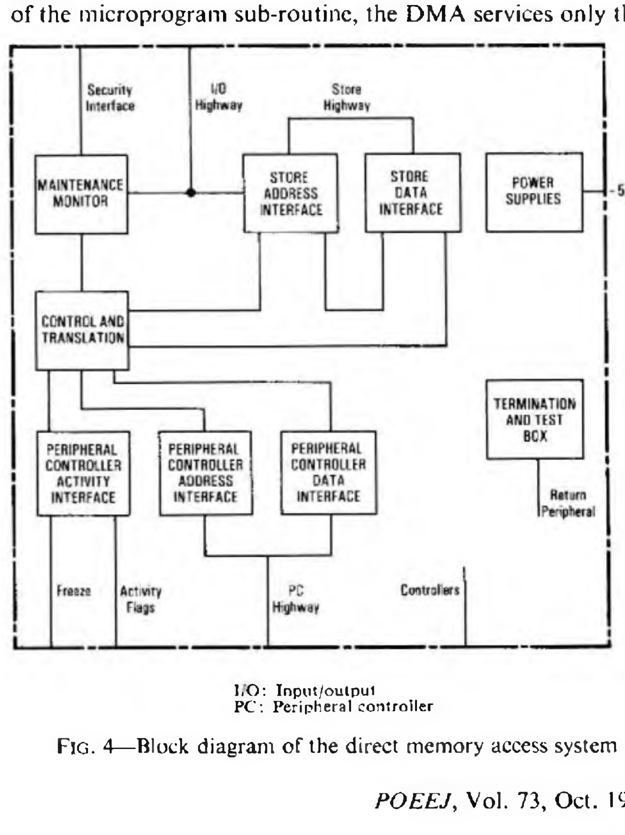
The function of the direct memory access (DMA) Unit is to allow access to the main shared-store without intervention by a CPU. The DMA also allows for the transfer of data at a higher rate than through direct I/O; this facility is required by an applications subsystem and the PU backing-store. A block diagram of the DMA system is given in Fig. 4.

The DMA is connected to the other PU facilities by the I/O highway, store highway and peripheral-controller highway, together with, in each case, the relevant *proceed wires* and security interfaces.

Data direction is controlled by *proceed* signals. A *fault-proceed* signal indicates a fault detected by the DMA unit or by the peripheral controller.

The DMA Interrupt Interface Input/Output Write Functions

All valid messages cause microprogram sub-routines to run after a *proceed* signal has been returned. Proceed action can only occur when the microprogram is running. On completion of the microprogram sub-routine, the DMA services only the



I/O: Input/output
PC: Peripheral controller

FIG. 4—Block diagram of the direct memory access system

I/O interface. However, READ access is possible with the DMA microprogram in any state. The DMA generates an *interrupt* signal if the microprogram stops.

THE PERIPHERAL CONTROLLER

The peripheral controller uses balanced line interfaces. Data direction on the unibus is controlled by *proceed* signals. A *fault-proceed* signal, when received instead of a *proceed* signal, indicates that the addressed peripheral-controller has detected a fault.

FUNCTION OF THE INDIVIDUAL PARTS OF THE INPUT/OUTPUT UNIT

The address port receives addresses broadcast on the I/O highways from the CPUs and their dedicated requests; the address port undertakes address decoding and port selection.

In the data port, data is transferred to and from the I/O highways. The data port also sends, under hardware command, *proceed* and *fault-proceed* signals.

The maintenance monitor supplies the block decode address with the correct number of address bits and takes requests from the I/O cables from which the selection is made. It also detects fault signals which are en route to the alarm equipment. An interface is also provided for the *unit-stood-down* condition.

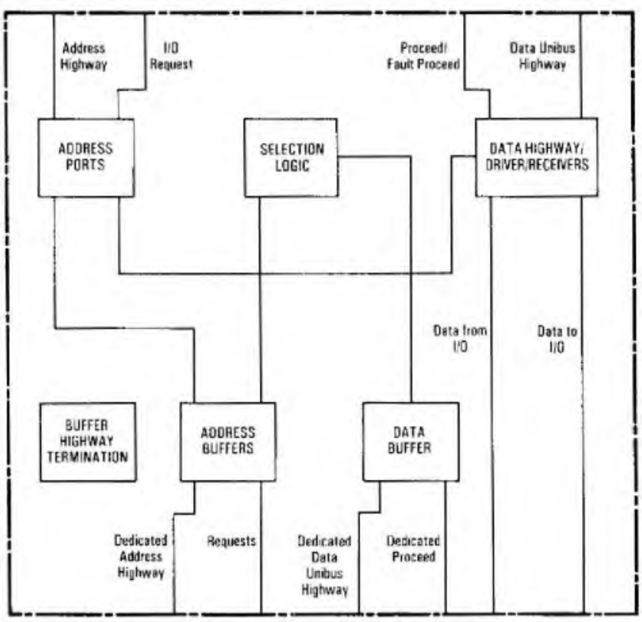
Data buffer handles the data and *proceed* signals to and from the I/O buffer highways and maintains the security over the buffer interface and the fault-data register, where data is assembled.

The address buffer deals with the transfer of address and buffer data to the I/O buffer highways. Some special requests are carried out in applications/peripheral equipment.

One block contains all I/O highway test boxes.

The console interface contains the serial-to-parallel and parallel-to-serial conversion circuitry for the link to a remote console, and contains all level-changing logic and registers for console information. Buffer highways have test boxes available or can be used with I/O expanders. The PU I/O expander allows connexion for an I/O block to additional request-data blocks.

A block diagram of the input/output system is given in Fig. 5.



I/O: Input/output

FIG. 5—The input/output system

PROCESSOR SOFTWARE

Each PU is equipped with software to enable the hardware to provide the processing facilities required by the applications programs. The software can be divided into 4 main areas:

(*a*) the mechanism for allocating processor time to a process, and storage (where appropriate) to PU users;

(*b*) the man-machine communication to the PU and the exchange;

(*c*) the facilities for communicating with other exchange PUs or the local administration centre (LAC) via the message transmission subsystem (MTS); and

(*d*) the mechanisms for detecting and recovery from failure conditions.

Off-line software packages are also provided to assist in loading the machine.

THE PU OPERATING SYSTEM

The operating system (OS) is that part of the software which is independent of the applications using the machine. The OS is responsible for the efficient running of the machine and for providing all the facilities required by the applications programs. These facilities include running programs, communication between programs, controlled recovery in the event of failures, storage management, timing and man-machine communication.

Process Allocator

Most of the software is implemented as entities called *processes*. Each process has a limited area of access which will include dedicated program and data. The area of access may also include some program and data shared with other processes. Each process is given a unique priority and, at a particular time, will be in one of the following possible states (see Fig. 6):

(*a*) running (executing code on a CPU),
(*b*) blocked (awaiting work, in the form of a task),
(*c*) suspended (awaiting a CPU), or
(*d*) trapped (awaiting clearance of a fault).

The process allocator (PA) provides the mechanism to change the process states. The PA is central to the operating system and is implemented identically within the microprogram of each CPU. The operating system performs the following functions:

Scheduling

There must be a process running on each in-service CPU at all times. The PA ensures this and also that the processes being run are the highest priority ones with work to do. Maps are maintained of processes which are eligible to run on each CPU and of processes which are suspended.

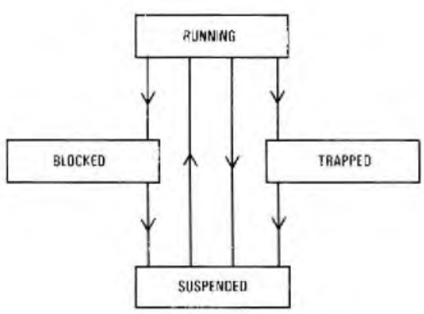


FIG. 6—Possible process states

Task Passing
Task passing is the main method of inter-process communication. Processes can pass blocks of information to other processes. The originating process makes a call to the PA to initiate the task passing. The first word of the task contains an index from a table which is examined by the PA to determine which process is to receive the task. The receiving process makes a call to the PA when it wishes to receive a task.

Interrupt Handling
All interrupts are steered to the PA on the CPU which is running the lowest priority process (known as the *LCPU*). The PA then suspends the process which is running and deals with the interrupt, an action that requires the PA to hand tasks to the appropriate process and then reschedule the CPU, or merely to reschedule.

Trap Handling
The PA detects when a process tries to carry out invalid operations, such as writing to read-only memory, and places the process in the trapped state. Details of the process and what it was doing are then handed in task form to the TRAP process, as described later.

Overload Control
The PA monitors the task queues of each process. When the queues go over or under specified levels, the PA hands tasks to the overload control subsystem for remedial action to be taken.

The above functions are not independent of each other. A single PA call may involve a combination of the functions. For example, consider a process handing a task to a process which is blocked awaiting this task. The PA on the CPU running the handling process will examine the priority of the receiving process; if this is higher than the process on LCPU, then the PA will initiate an interrupt. The interrupt will go to the PA on LCPU, which will reschedule the CPU and get the receiving process running with the received task. In this example, the PA has carried out task passing, scheduling and interrupt handling as the result of a single PA call.

In performing the functions, each PA in each CPU works independently. However, there is a common data area for such things as the map of suspended processes. If a PA wishes to write to this common data area it engages a lockout, which will cause other process allocators to queue for access to this area.

Storage Allocator

The management of the PU storage system is effected by a process called the *storage allocator*. The main function of the storage allocator is the control of the 2 levels of store, mainframe and backing store, and the transfer of data between them.

Storage is grouped into pages, each of which contains 256 words. Processes on the PU always use virtual addresses, which are translated by the hardware to physical addresses each time a fresh page is used. This translation uses 2 tables: the first, called the *process page table* (PPT), gives the system virtual address for a given process virtual address; the second, called the *system page table* (SPT), gives the physical address of the page from the system virtual address. However, not all procedure and data will be in the mainstore at all times. If during translation a page is found not to be in mainstore, then the process attempting access will be trapped whilst the storage allocator fetches the page from the backing store.

This operation will be transparent to the process, apart from the delay caused. If required, important pages can be kept in mainstore permanently. Processes that access pages which are not kept permanently in store can avoid being trapped by making specific requests to the storage allocator for pages to be brought into mainstore in advance. Rollback versions of each page are kept on backing store mainly for use by the storage allocator in the event of failures.

A file system is provided mainly for the convenience of the storage allocator and the compiler system operations. A *file* is a group of pages with consecutive process virtual-addresses which have the same status (that is, EXECUTE, READ ONLY or READ/WRITE).

A file consists of one of 256 pages of information. All the file pages accessible to a process have the same status for that process. A process has one procedure file and a fixed number of data files. For each file, the process has an associated u and v number: the numbers u and v indicate the virtual page address of the first page in the file; the succeeding pages in the file have successive values of v, but the same value of u.

There are corresponding entries in the process page table whilst the file is open. Files may share part of the process virtual-address space. In this case, only one file may be open at a time and the other file or files are closed and are not directly addressable by the process. The open file must be closed before another can be opened. Closing a file will not cause any loss of information.

Each process has an associated process file table. Each file that is accessible to a process has an entry in the file table, which contains the access status of the file to the process—the u, v and an index r number. The file is referred to in the process by a file number f, which is used as an index down the process file. The storage allocator uses the displacement r to index down the system file table to an entry containing a pointer to the file-page table for that file. Each page in the file has an entry in the consecutive process virtual-addresses, and each is of the same status (that is, EXECUTE, READ ONLY or READ/WRITE).

A process has at least 3 files, one of each status. The storage allocator provides facilities to manipulate code and data on a file basis when this is more convenient than a page basis. This entry contains an index x down the system page table (if there is an entry in the system page table for the page), and the store address for the page.

An entry may consist of more than one word. The file page table length is specified in the system file table.

Each page has an 8 bit page number, g, within the file. If a *trap-not-in-main-memory* state occurs, the storage allocator can use the values of r and g in the system page table to obtain the backing-store address of the page via the systems file and file page tables. The backing-store address corresponds to 2 physical addresses for 2 copies of the page on different backing-store units.

Interrupt and Timing Process

The interrupt and timing process (INTIM) provides timing data which includes the time and date, interval timing and periodic timing. This data is supplied by INTIM in tasks, but the time and date can also be obtained by a process reading INTIM's software calendar.

The INTIM also provides interrupt facilities in conjunction with the PA. Applications programs will inform the INTIM of which interrupts they wish to be informed. The INTIM will arrange for the PA to note when these interrupts are triggered. The PA will hand tasks appropriate to the triggered interrupts directly to the applications programs.

Background

A background process is provided for each CPU. Background processes are the lowest priority processes on the machine and ensure that the CPUs have a process to run at all times.

Failure-Detection and Recovery Rollback Process

A facility used in the failure detection and recovery mechanism is termed the *rollback* process. With this facility, failure situations can be detected and the programs and data relevant to a particular activity can be re-run. The amount of program and data re-run will be increased from a very small amount initially (that amount which could be expected to produce the correct output) to a complete system re-run if this is necessary to correct the defect.

Rollback Requests

Rollback requests are made when a process suspects another process or suite of processes of being faulty. These requests are in the form of a task to the rollback process.

A process cannot request the rollback of any process; a number of pre-specified requests only are possible. These requests are determined by the task index table of the requesting process. The requesting processes do not need to know any process indices, this information is inherent in the task index tables and other operating system data.

Hardware faults on the CPU, the mainframe store, the backing store and the I/O can cause processes to be rolled back and data refreshed if data is lost or corrupted.

Rollback Reports

Rollback reports show the rollback action taken to recover from a hardware or software fault. Rollback may output tasks to a TYPER process via the maintenance control subsystem to print-out the identity of registers of a trapped process (caused by a software trap).

MAN-MACHINE INTERFACE

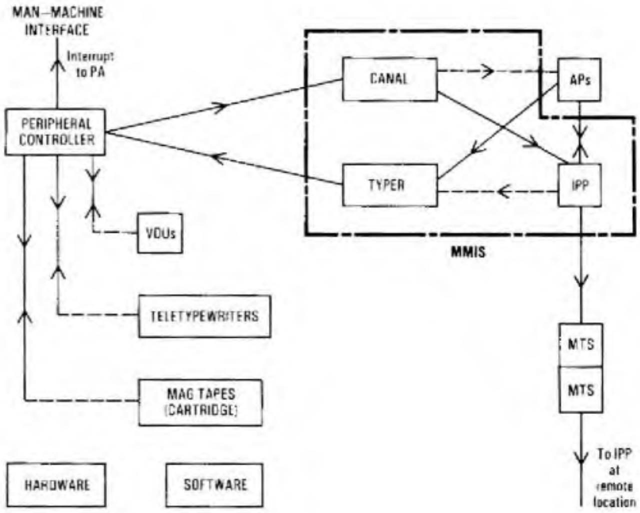
The man-machine interface subsystem (MMIS) is not really a subsystem, but it is a functional entity within the PU subsystem software. The MMIS comprises 3 on-line processes: the command analyser (CANAL) process; the TYPER process; and the interface package process (IPP). These processes enable other processes to communicate with locally or remotely-sited man-machine peripherals.

The CANAL process receives lines of input characters from the hardware peripheral controller, checks for syntactical errors, and analyses the input to decide which applications process (AP) should receive the input. The CANAL process then passes the input to the AP in a format specified by the AP, or generates appropriate responses back to the peripheral device.

The TYPER process takes buffers of data from an AP and generates the output characters in a format specified by the AP; the output characters are passed to the peripheral controller for output to the peripheral device. The commands required to control the magnetic-tape cartridge machines are generated by the TYPER process under the control of the AP that requires an input from a cartridge.

The IPP, in conjunction with the System X Message Transmission Subsystem (MTS), provides communications between local processes (for example, at an exchange) and remote processes (for example, at an LAC) such that man-machine commands which are input locally can be carried out remotely, and to enable the transmission of administration data from an AP to another AP at a remote location. The IPP also detects failure of the MTS link and, using the cartridge control facilities of the TYPER process, diverts information to a local back-up store cartridge until the MTS link is re-established. The contents of the back-up cartridge are later transmitted to the remote location. The main MMIS interfaces are shown in Fig. 7; the CANAL and TYPER processes present similar interfaces to the APs and the IPP, and the IPP also interfaces with the MTS.

The man-machine language for input, known as *UNKCLE1* (United Kingdom CCITT Man-Machine Language No. 1), and the supporting control procedures are designed to be compatible with the International Telegraph and Telephone Consultative Committee (CCITT) recommendations for



AP: Applications program
IPP: Interface package process
MMIS: Man-machine interface subsystem
MTS: Message transmission subsystem
PA: Process allocator
VDU: Visual display unit

FIG. 7—Block diagram of the man-machine process

man-machine communication. Man-machine instructions take the form of a command code followed by one or more blocks of parameters. The command code specifies the resource to which the instruction is to be directed and the action which is to be performed on the resource. The initial verification of the command code and the checking of the man-machine language syntax is done by the CANAL process, which can output, via the TYPER process, standard error messages when necessary. Man-machine instructions can also be input from the magnetic-tape cartridge devices. In this case, a keyboard terminal device is used to instruct the CANAL process to allocate a drive for this function and to instruct the AP to request cartridge input.

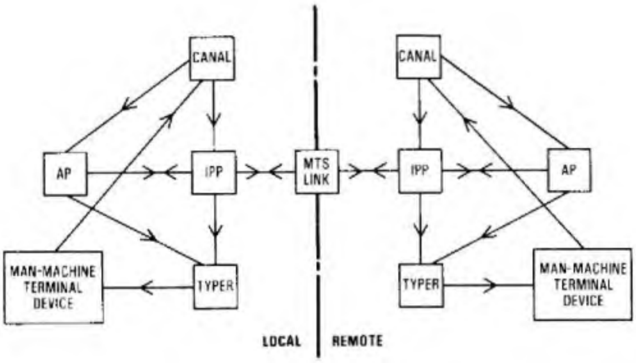
The CANAL process is then able to issue cartridge control commands via the TYPER process and to deal with the spanning of track and volume boundaries, facilitated by the use of extended ISO cartridge labelling standards.

Security of access to the software is provided by the CANAL process password-level system. All man-machine inputs and responses are recorded by a logging process which gets the details from the CANAL process (via the IPP if remote).

Outputs can be sent to one or more devices and can be diverted automatically if an output device is unavailable.

The IPP provides communication between the APs and man-machine terminals at different locations. Man-machine characters (ASCII) are routed via the CANAL and TYPER processes to and from the IPP, but binary data to be sent from one AP to another is passed directly to the IPP, as shown in Fig. 8. The remote IPP receives the bundles of messages from the MTS link, reconstructs the buffers, and passes them on to the destination AP or to the CANAL process in the same order as they were received by the local IPP.

Complete bundles of messages are acknowledged by the receiving IPP, which can also detect loss of individual messages and send a negative acknowledgement. Message loss is corrected by re-transmission by the sending IPP. Link verification and flow control messages are also sent between the two IPPs and are used to detect failures and overload of the MTS link. Under conditions of MTS failure or overload, bundles are diverted via the TYPER process onto the LAC back-up



AP: Applications program
IPP: Interface package process
MTS: Message transmission subsystem

FIG. 8—Block diagram of a communication path routed via IPPs to a remote location

store (a set of dedicated magnetic-tape cartridges), until the link is re-established. Diversion to the LAC back-up store is then stopped, and a message is sent from the IPP to the irregular input process (IIP) at the LAC. The IIP can then request the IPP to transmit the diverted information by using the CANAL process to access the LAC back-up store cartridge drive.

The IPP therefore provides a means whereby information can be passed between processes at separate locations without the need for the processes to be involved in the management of the transmission link, and also provides the facility for man-machine transactions to be carried out by remote control.

LOADING AND EDITING

The LOADER process is an on-line process which allows system files to be entered, altered and tested under control from a man-machine terminal. Since the LOADER process is used when the processor subsystem is working in an operational telephone exchange, the data checking and the trial procedures are designed to protect the rest of the system against errors in the loaded or edited files.

Data input, normally from cartridge, to the LOADER process is in the form of a series of commands in the LOADER process language. These commands allow information relating to each process, file, and page to be input together with the virtual address (u, v) and the list of data contents for each page. The LOADER process checks the input for consistency, not only within the files being loaded but also for consistency with other files already loaded onto the system. When the LOADER process has checked the input, it sends the information to the storage allocator, which amends the system data tables and updates the rollback copies on the backing store.

PU SECURITY, FAILURE DETECTION, RECOVERY AND FINE DIAGNOSTICS

Security

The processors are divided into distinct security units (CPU, STORE, etc). A faulty unit can be withdrawn from service to allow the remainder of the PU to continue to function. Faults are detected within each unit by a number of mechanisms such as parity checks, time-outs, cyclic redundancy checks, and software routines including validity checks. Fault detection is also provided by parity checks being carried out on the ROM output fields. A highway is provided to monitor all toggles and registers.

Detection of PU Failure

A security unit, having triggered a detector, is taken out of service and software is run to confirm the existence of a fault. If a fault is confirmed, the security unit remains out of service awaiting repair action. If a fault is not confirmed, it is returned to service and a record kept of a transient fault; maintenance attention is initiated only if transients occur too frequently.

The failures in the PU are divided into 2 main areas. The first covers those failure conditions where the failure detection mechanism within the PU detects a fault and is able to recover from it by 'standing down' the failed item and replacing it with a working unit. The second involves determining the precise cause of the failure within a hardware area. Diagnostic software is provided to assist the maintenance staff to undertake this work.

Fine Diagnostics

Diagnostics software is a term to describe a set of software facilities used to resolve the location of a fault to a slide-in-unit (SIU) within a 'stood down' security unit. The diagnostic process consists, in part, of a software module per security unit and is brought into action automatically by the MCS after receiving a fault report from the PU OS. Each diagnostic module is of a tree-structure and initiates problems (bit patterns) via the hardware to a fault register within the security unit. The results in the fault register are analysed by the software and a fault number is output locally or to the LAC, from which the faulty SIU can be identified and replaced. A further diagnostic facility is available via the MMI, which allows a limited but powerful variation of the 'problem' to be offered to a security unit by a maintenance technician.

CONCLUSION

The requirements of the System X switching units for very reliable real-time computing facilities operating within, and providing the features required by, the software built to System X standards are being met by the processor utility described. The concept is providing the basis for satisfactory operation and management of the switching units within an existing network.

ACKNOWLEDGEMENTS

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System X: Subsystems

Part 4—Common-Channel Signalling and the Message Transmission Subsystem

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UDC 621.395.34: 621.394.4: 681.327.8

The general principles and advantages of using common-channel signalling (CCS) for System X exchanges have been described in a previous article[1] in the Journal. The CCS system adopted for the System X project is based on the CCITT Signalling System No. 7, which is described in this article. Description is also given of the message transmission subsystem, which performs the message transfer functions for the signalling system in accordance with CCITT specifications. For the purpose of comparison, a brief description of the operational features of the CCITT Signalling System No. 6 is also included.*

INTRODUCTION

The use of common-channel signalling (CCS) allows direct communication to be made between the processors of different exchanges for call control and other purposes; this is achieved by using separate dedicated signalling links interconnecting the exchanges over which call-control messages are sent. Because one link can carry signalling messages for a large number of traffic circuits, the need for signalling equipment on a per circuit basis is avoided. The message formats are compatible with the way in which the exchange processors handle calls so that signalling conversion is minimized and the signalling links appear as transparent carriers to the call processing functions. The use of messages allows any signalling conditions to be transmitted; thus new facilities requiring additional signals can be easily introduced. The signalling is fast, such that routeing information derived from customer-originated dialled or keyed sending is transmitted as fast as it is originated, thus significantly reducing the post-sending delays compared with the delays which arise in the existing network.

The signalling links also enable other information besides call-control signalling to be transmitted. Links between exchanges and local administration centres (LACs) enable management, maintenance, and statistical information to be transferred.

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SPECIFICATION BY THE CCITT OF COMMON-CHANNEL SIGNALLING SYSTEMS

Although the concept of common-channel signalling (CCS) has existed for many years, it was not until the advent of common-control systems, and in particular those in which computer-type processors were used for control, that the realization of CCS began to develop.

The first well known system was the CCITT* Signalling System No. 6, which was first specified for international use in 1968[2]. This system was originally intended for use on data links provided over analogue circuits fitted with 2·4 kbit/s modems. However, the system was later enhanced to allow it to operate over circuits derived from pulse-code modulation (PCM) systems and to operate at a faster speed.

The British Post Office (BPO) and the GEC Ltd participated in an international field trial which proved the feasibility of CCS and provided valuable operational experience. CCITT No. 6 signalling was first used for international service in July 1978 and was brought into service for circuits between the UK and the USA in January 1980. The system will be the subject of an article in a future issue of the *Journal*.

Although intended primarily for international use, CCITT No. 6 signalling has been adapted for national use by some administrations. For example, it is used by the Bell System[3] for inter-regional signalling, and is referred to as *common-channel inter-office signalling* (CCIS).

The following is a brief description of the key operational features of the CCITT No. 6 system.

(*a*) Signal messages comprise one or more fixed-length signal units (SUs).

Editor's Note: The normal editorial practice of defining abbreviations at their first appearance only has not been adopted in this article; instead the abbreviations, summarized below, have been defined frequently throughout the text to aid identification.

SUMMARY OF ABBREVIATIONS USED IN THIS ARTICLE

BIB:	Backward indicator bit	MP:	Management process
BSN:	Backward sequence number	MRP:	Message routeing process
CCS:	Common-channel signalling	MSS:	Management statistics subsystem
CPS:	Call processing subsystem	MSU:	Message signal unit
DIO:	Direct input/output	MTP:	Message-transfer part
DLT:	Digital line termination	MTS:	Message transmission subsystem
DPC:	Destination point code	MUX:	Digital multiplex
DSS:	Digital switching subsystem	OPC:	Originating point code
DSSS:	Digital subscriber switching subsystem	PCM:	Pulse-code modulation
FIB:	Forward indicator bit	PU:	Processor utility
FISU:	Fill-in signal unit	RTU:	Remote terminal unit
FSN:	Forward sequence number	SIU:	Slide-in unit
GPL:	Group processing logic	SLS:	Signalling link selection
GTU:	Group terminal unit	SP:	Signalling point
LAC:	Local administration centre	ST:	Signalling terminal
LSSU:	Link-status signal unit	STP:	Signal transfer point
MCS:	Maintenance control subsystem	SU:	Signal unit
MDP:	Message discrimination process	TUP:	Telephone-user part
MMC:	Man-machine communication	ULA:	Uncommitted logic array

(*b*) A full duplex SU synchronous mode of transmission is used. (The two directions operate in a plesiochronous mode.) A synchronization SU is used to achieve synchronism in each direction of transmission.

(*c*) Error detection is achieved by use of check bits in each SU.

(*d*) Acknowledgement of the state of correctness of the received SUs is sent on a block basis.

(*e*) An error detected in any received SU is corrected by retransmission of the complete message.

(*f*) The error control is such that the probability of a message containing an undetected error being delivered is negligible. However, in some circumstances, the system does allow superfluous messages and messages in the wrong order to be delivered. To overcome this problem, the system incorporates check procedures whereby the received signal messages are analysed to check that they have not been duplicated and to check if their reception at a particular point in a sequence of signals is reasonable. This problem does not arise in the CCITT No. 7 system to any significant degree.

(*g*) The CCITT No. 6 system accommodates a repertoire of signalling messages; their formats and use are defined for telephony.

(*h*) Management procedures are defined for the control and use of signalling.

(*i*) Signalling links are used on a point-to-point basis, and the permitted modes of operation include the use of quasi-associated signalling whereby intermediate signal-transfer points (STPs) may be used for transferring messages relating to traffic circuits between two or more other exchanges.

(*j*) The system is specified for telephony signalling only.

CCITT SIGNALLING SYSTEM No. 7

The CCITT Signalling System No. 7 has been adopted for use in System X. It is a system which has been optimized for use in a digital environment and which has been specified with a particular view of its adoption for use in national networks as well as for international signalling. The BPO has taken an active part in the studies involved and in the production of the specification of the system. The specification is due for ratification by the International Telecommunication Union towards the end of 1980, which coincides with the end of the current CCITT plenary period.

Although changes have been incorporated in the CCITT No. 7 system specification as it evolved, the description given in an earlier article[1] for the BPO Signalling System Common-Channel No. 1 (SSCC No. 1), which is based on the No. 7 system at an earlier stage in its development, is still correct with respect to the current CCITT No. 7 system specification. The differences which now exist between the CCITT No. 7 system and SSCC No. 1 are of a more detailed nature and do not affect the description at this level. SSCC No. 1 is to be replaced by the current CCITT No. 7 signalling system.

Operational Features

The operational features of the CCITT No. 7 system are as follows:

(*a*) Signal messages are transmitted as message signal units (MSUs). These may vary in length up to a normal maximum of 544 bits; the actual length is indicated by a length-indicator field within the MSU. In addition, there are link-status signal units (LSSUs), which are used for link control purposes, and fill-in signal units (FISUs), which are transmitted when there are no other MSUs for transmission. The format of an MSU is shown in Fig. 1.

(*b*) Because signal units (SUs) may vary in length, there is no continual SU synchronism. Instead, the start of each SU is identified by a flag, as described in a previous article[1].

(*c*) Error detection is achieved by use of check bits in each SU. A message has a single check field.

(*d*) Acknowledgement of the state of SUs received is carried by all SUs in the backward direction. In the forward direction, each MSU is identified by a forward sequence number (FSN). In the backward direction, each SU carries a backward sequence number (BSN) and a backward indicator bit (BIB) for acknowledgement purposes.

(*e*) An error detected in a MSU is corrected by retransmission of the complete message, followed by retransmission of all the subsequent MSUs which have been sent. This is cyclic retransmission and avoids the need to store MSUs in the receiving part of a signalling terminal (ST) while awaiting a retransmission.

(*f*) Procedures are incorporated which allow automatic change-over with message retrieval in the event of a signalling link failure. This facility is used in a situation where more than one signalling link is provided for security, and results in MSUs being delivered to a user in the correct order, and without the loss or repetition of information when a signalling link fails.

(*g*) A repertoire of signalling messages, formats, and protocols for telephony applications is defined separately in a specification for the telephone-user part (TUP).

(*h*) Signalling network functions are defined in considerable detail for the basic message handling and, in particular, for the more complex functions of managing signalling traffic, signalling routes, and signalling links.

(*i*) Signalling links are used on a point-to-point basis and quasi-associated signalling with one or more signal transfer points may be used, as well as associated signalling.

(*j*) The system permits other user parts in addition to the TUP.

Functional Breakdown

For purposes of specification, the CCITT have defined 4 functional levels in the specification of the CCITT No. 7 system, as shown in Fig. 2. Levels 1–3 are contained within the message-transfer part (MTP), which is currently the major part of the signalling system specification. The MTP is implemented in System X by the message transmission sub-system (MTS). Level 4 is termed the *user part* and is covered by a separate specification for each user. The telephone user part (TUP) is the main user and is implemented in System X by the call processing subsystem (CPS).

The functional levels are not intended to imply a particular implementation; therefore, detailed specifications for the interfaces between the levels are not provided. The levels are hierarchical in nature with level 4 at the top, and it is the

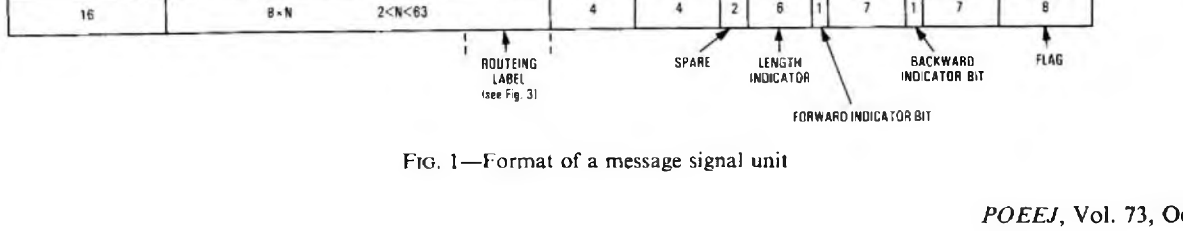


Fig. 1—Format of a message signal unit

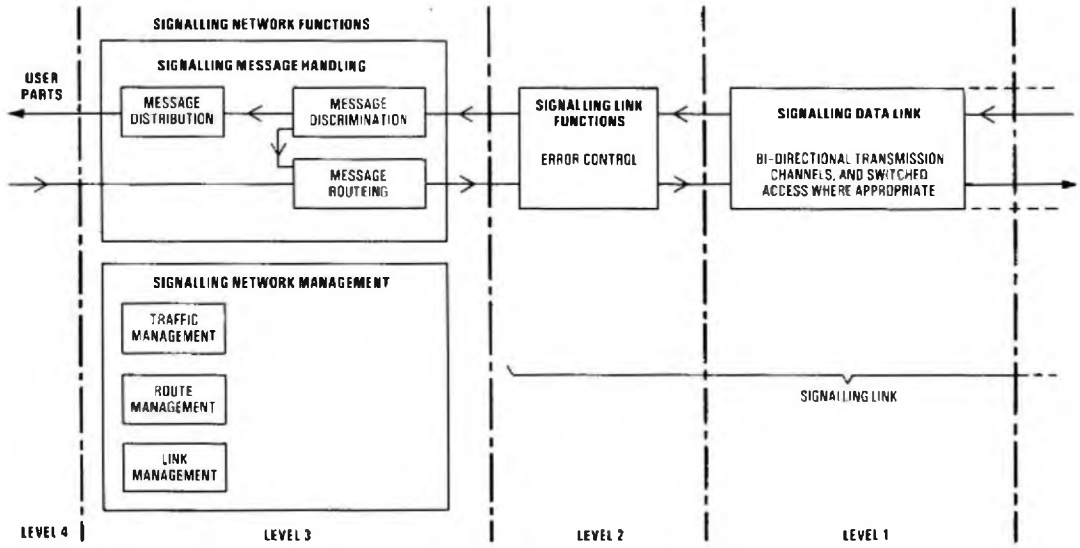


FIG. 2—Functional levels of the CCITT Signalling System No. 7

functions which the levels have to perform that are specified in detail.

The information to be sent over level 1 is specified in detail because this is the boundary between different administrations for international signalling.

The main functions performed within each level are as follows:

Level 1

Level 1 contains the signalling data link functions. The level comprises a full duplex data link and the means to access it from level 2. In System X it is normally a 64 kbit/s PCM channel derived from a PCM system which is accessed via a digital multiplexer and a semi-permanently switched path through the digital switching subsystem (DSS). Where PCM systems are not available, such as in the case of links to a local administration centre (LAC), then analogue circuits, fitted with 4·8 kbit/s modems at each end, are used.

Level 2

Level 2 contains the signalling link functions. These functions enable the correct transfer of messages over a single signalling data link. They ensure that messages are delivered in the correct order, without loss or duplication, in the face of line error rates up to a defined limit, beyond which the link is deemed to have failed.

Level 3

Level 3 contains the signalling network functions. Two of the main functional categories are

(*a*) the message-handling functions, which deal with the transfer of messages between a user (level 4) and the appropriate signalling links, and vice-versa, and the control of link changeover and message retrieval, and

(*b*) the signalling network management functions, which deal with control of the network and message routeing according to the current state of the network; these functions control reconfigurations and other actions required to preserve, or to restore after failure, the normal message transfer capability.

Level 4

Level 4 contains the user-part functions. For the telephone-user part (TUP) these functions are defined as part of the signalling system in the TUP specification, which defines the signals and procedures to be used for the control of telephone calls. Other user-part functions may be defined separately from the signalling system specification; for example, the transfer of bulk data which could be assembled from, and disassembled to, message signal units (MSUs) for transfer over the message-transfer part (MTP).

The Signalling Network

The CCITT specification for the message-transfer part (MTP) defines a signalling point (SP) as a network node at which CCS is provided. A number of signalling links directly interconnecting two SPs, which are used collectively to provide the signalling capability between them, is referred to as a *signalling link set*. There can be 1–16 signalling links in a set over which the signalling traffic may be shared, but in the UK national network the number will be limited to four.

Modes of Operation

In the associated mode of operation for the telephone user part, the signalling between two directly interconnected SPs is associated with the telephony traffic circuits between them.

In the non-associated mode, the signalling between two SPs may follow a different route to that of the traffic circuits for which they carry the signalling, and the route may pass through one or more intermediate signal transfer points (STPs).

The quasi-associated mode is a limited case of the non-associated mode, in which the signalling for each group of traffic circuits follows a predetermined route. More than one route may be specified for security reasons. For example, the typical case is where a quasi-associated signalling route is used as a back-up route for an associated route.

Message Routeing

Each user message contains two SP codes for routeing and management purposes. These are aptly named the *originating point code* (OPC), which uniquely defines the SP at which a user message is originated, and the *destination point code* (DPC), which defines the SP for which the message is destined. The location of these codes in the message format is shown in Fig. 1 and the format of the routeing label is shown in Fig. 3. Also shown in Fig. 3 is a signalling link selection (SLS) field, which is used to select a particular link in a signalling link-set, at each SP, over which a particular message is transferred. The SLS enables signalling to be shared over the links in a link-set.

All messages relating to a particular traffic circuit have the same SLS code. This ensures that all messages relating to a particular telephone call are transferred over the same links, and are thus delivered in the correct order.

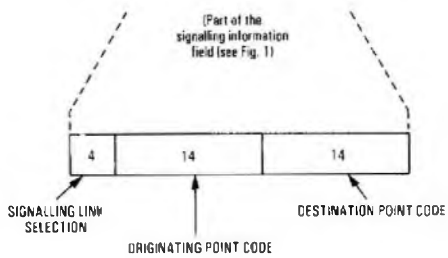


FIG. 3—Format of the routeing label

THE UK COMMON-CHANNEL SIGNALLING NETWORK

Plans for the UK CCS network are currently being formulated and hence it is not yet possible to describe the network in detail at this time.

It is probable that in the main network all mandatory traffic routes will have associated CCS routes with 2 links in a set normally being provided. Link sets of 3 or 4 links can be provided where the level of signalling traffic or the security requirements warrant this.

Not all traffic routes will have associated CCS; in such cases, use will be made of quasi-associated signalling via signal transfer points (STPs). The use of STPs reduces the number of signalling links which are needed in the network, but increases the processing power required at signal points (SPs) when they are also STPs. In general, small traffic routes may be more economically served by the use of quasi-associated signalling, particularly if this avoids the provision of signalling links over analogue circuits. In such cases, consideration must be given to the additional cost of providing data modems for the signalling terminals (STs).

An STP also involves additional message-handling times and it is therefore desirable to minimize the number of STPs through which a particular message has to pass.

SECURITY

Signalling routes are normally secured by the use of 2-link signalling link sets with automatic change-over in the event of a single link failure. Ideally, diverse routeing of the signalling data links over line plant will minimize the chance of a route failure, but irrespective of this, additional security can be gained by the provision of alternative signalling routeings which make use of STPs.

Alternative routeing will also provide security against the failure of an STP by enabling a different or other STPs to be used in its place.

The network management functions enable these facilities to be provided. When a normal route becomes unavailable, the information is sent to SPs and a nominated alternative route is selected. Since all messages carry a destination point code (DPC), the messages can be routed to their correct destination, provided that the routeing is permitted for that DPC.

Where alternative routeing is provided it is necessary to ensure that messages cannot be routed around a continuous closed loop as a result of fault conditions or incorrect routeing.

THE MESSAGE TRANSMISSION SUBSYSTEM

The message transmission subsystem (MTS) is implemented as a combination of software, firmware, and hardware which performs the message-transfer part (MTP) function for the UK national subset of the CCITT No. 7 system in accord with the CCITT specification for the MTP.

A previous article[4] briefly described an earlier development of the MTS for digital trunk exchanges. A variant of MTS was also developed for use in small local exchanges to provide a more cost effective implementation for applications where few signalling links are required. Since then, advances in technology have enabled the development of a single version of MTS for use in all applications, including international signalling and remote control signalling for the digital subscriber switching subsystem (DSSS). The development of this version of MTS is tending towards a single slide-in-unit (SIU) per signalling link.

A few early System X exchanges use the local exchange version of MTS. However, changes have since been incorporated in the CCITT No. 7 system specification to both the position of various fields within SUs and to the order in which the bits in these fields are transmitted. This results in the early MTS signalling terminals being incompatible with the present ones and, to avoid future interworking problems, it is planned to replace these as soon as possible with new ones. This was an unavoidable and not unexpected requirement, since designing to an emerging international specification has obvious risks when assumptions have to be made concerning the final specification.

MTS Requirements

Apart from conforming to the CCITT No. 7 System specification, the MTS has to meet the operational requirements of System X. The chief requirements are as follows:

Size
The MTS must be capable of easy extension from a minimum size of two links to a maximum size in the region of 1000 links for large tandem exchanges.

Cost
The MTS must meet cost targets, particularly for the small local exchange application and when CCS is first introduced. In practice, this means that the amount of equipment required to perform the functions common to all size ranges must be minimal.

Traffic Capacity
Traffic capacity may be expressed in terms of both average and peak messages per second for each link and also for the MTS as a whole. In addition, it is necessary to meet the message transfer time requirements under various loading conditions. A typical figure based on the larger exchange requirements is the ability to handle over 3000 messages per second for an exchange handling up to 500 000 busy-hour call attempts. An individual signalling terminal will be required to handle up to 200 user messages per second, on average, during the busy hour. This level of traffic corresponds to an approximate link occupancy of 0·2 in each direction, but would only occur under multiple failure conditions in the signalling network.

Message Transfer Times
The CCITT No. 7 system specification defines where message transfer times are measured, but the values given are provisional and will be the subject of further studies. Typical requirements proposed for messages transferred between users (level 4) at each end of a single link are for a mean transfer time of 25 ms, with no more than 5% of messages exceeding 75 ms. In addition, for each signal transfer point (STP) involved in a transfer, a mean transfer time of 25 ms through the STP is proposed, with no more than 5% of messages exceeding 40 ms.

MTS Implementation

A block diagram of MTS is shown in Fig. 4. The MTS consists of 3 software processes which operate on the processor utility (PU)[5] and communicate with the hardware via the direct input/output (DIO) mechanism of the PU. The processes are the message-routeing process (MRP), the message-discrimination process (MDP), and the management process

(MP). The hardware consists of 3 basic types of slide-in unit (SIU), and is given access to either 64 kbit/s PCM channels via a digital multiplex and the DSS, or to 4·8 kbit/s data modems.

Between levels 4 and 3, the user interface is a task-passing interface between the call-processing subsystem and the message-routeing process and the message-discrimination process.

The Message Routeing Process

The message routeing process (MRP) receives messages in the form of tasks from the call processing subsystem (CPS) and routes them to the appropriate area of the hardware for transmission over a signalling link. The routeing is based on an analysis of the routeing label, inserted in the message by the user, which contains the destination point code (DPC).

Other messages are passed to the MRP from the message discrimination process (MDP), for which the MTS is acting as a signal transfer point (STP).

Should the amount of signalling traffic warrant it, the MRP and MDP can be replicated. In this case, an MRP may receive STP messages from more than one MDP. Also, under some circumstances, an MRP may be unable to route a message correctly with the hardware to which it has access. The MRP can then transfer the message to another MRP which is able to route it correctly.

Apart from user messages, the MRP routes network control messages from the management process; the messages are identified in the service information octet.

The MRP provides statistical information on the number of messages handled to the management statistics subsystem (MSS) on a periodic basis.

The Message Discrimination Process

The message discrimination process (MDP) handles messages from the hardware which have been received over the signalling links and discriminates between those messages which are transit and those which are to be terminated, by examining the destination point code in the routeing label. The transit messages are passed to the appropriate MRP for further transmission and the messages to be terminated are routed to the required user according to the service information octet.

When process replication is required for traffic reasons, then the MRPs and MDPs are added in pairs.

The Management Process

The management process (MP) handles the management and maintenance functions of the MTS and, for this purpose, communicates with the maintenance control subsystem (MCS), the DSS, and the other processes and hardware of the MTS.

Management commands via the man-machine communication (MMC) of the MCS allow control of the MTS configuration and enable system data to be changed as required. Communication with the DSS enables control of the semi-permanent paths through the DSS for the provision of the signalling data links.

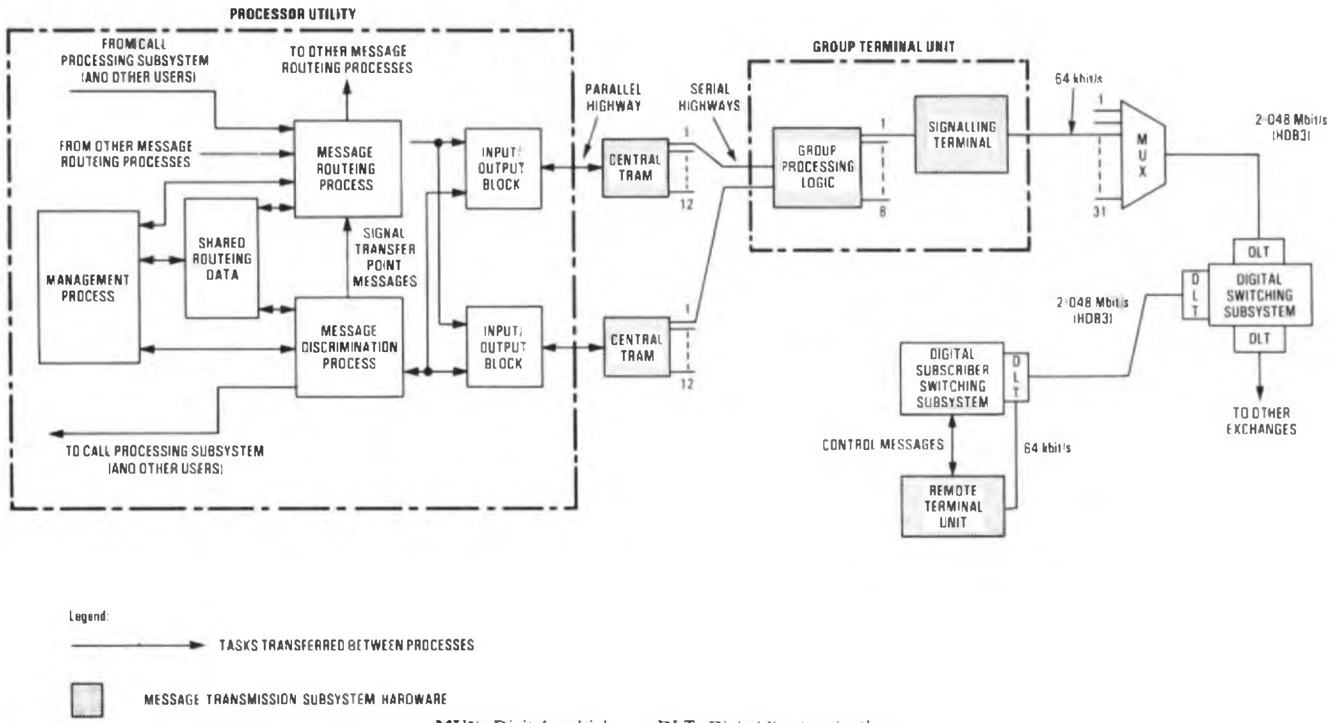
The MP performs checks on itself and the other processes and the MTS hardware. It requests status reports periodically from the MTS hardware via the MRP and the MDP, and sends periodic test messages to the hardware and to other MTS installations via the signalling links. It responds to the status information sent over signalling links in link status signal units (LSSUs) and to management messages from other MTS installations, and sends fault reports to the MCS.

The MP carries out autonomously those functions which are required by the CCITT No. 7 system specification. These include the automatic change-over and retrieval of messages during link failure conditions and re-routeing of messages over a quasi-associated back-up link where appropriate. The MP is not replicated.

MTS Hardware

There are 3 functional units in the MTS hardware, as shown in Fig. 4. These units are the central *tram*†, the group terminal unit (GTU) and the remote terminal unit (RTU). In addition, a digital multiplex is required to give access to the DSS as part of the level 1 function.

† The name *tram* has no special significance but is derived from the word omnibus.



MUX: Digital multiplex   DLT: Digital line termination

FIG. 4—Block diagram of message transmission subsystem

Central Tram
The central tram is an input/output controller which interfaces between the processor utility DIO and the GTUs. The basic function of the central tram is to provide, at low cost, a fan-out capability between the DIO and up to 12 GTUs. This is achieved by using a high-speed serial interface to the GTUs for data transfer, with separate control lines, and by using an uncommitted logic array (ULA) device as part of the tram controller to minimize the number of components used.

The central tram contains a message buffer for each direction of transmission. Messages from the MRP are transferred to the correct GTU according to header information passed with messages by the MRP. The GTUs are scanned by the tram for messages received over links. Each message received is transferred to the tram, which then informs the MDP.

Group Terminal Unit
The group terminal unit contains the group processing logic (GPL) and up to 8 CCITT No. 7 signalling terminals (STs). Both the GPL and STs are implemented as single SIUs, each containing a microprocessor. The GTU performs mainly level-2 functions and some level-3 functions in conjunction with the software processes.

Signalling Terminal

The signalling terminal (ST) sends to and receives messages from the signalling data links. In the outgoing direction the ST generates the polynominal check field, inserts *zeros* as necessary, and adds the flag prior to transmission. In the incoming direction, it searches for flags, deletes *zeros*, performs the polynominal check and discriminates between fill-in signal units (FISUs) and other SUs. These functions are all performed by a ULA device.

In addition, in the incoming direction, a leaky-bucket error-rate count is maintained to enable the state of the signalling link to be monitored. User messages are stored for collection by the GPL. The backward sequence number (BSN) and the backward indicator bit (BIB) are examined for acknowledgements and retransmission requests. The status information of the link status signal units (LSSUs) is examined for requests to re-align the link etc.

In the outgoing direction, messages for transmission are received from the GPL. On command from the GPL, LSSUs can be transmitted repeatedly. When no new messages are received from the GPL, the ST will send FISUs continually.

Remote Terminal Unit

The remote terminal unit (RTU) is provided to enable control signalling between the PU and a digital concentrator of the digital subscriber switching subsystem (DSSS)†. This form of signalling is considered to be intra-exchange signalling, and as such it is not regarded as part of the national signalling network.

The use of the RTU permits the DSSS to be located either locally with, or remotely from, the PU and DSS, as required.

The RTU is the same basic slide-in unit (SIU) as the ST. It differs in terms of the microprocessor firmware which is stored in a memory on the SIU. The difference arises because of the type of signalling involved and because the RTU is not associated with a GPL. The RTU performs the same basic functions as the ST but interfaces with the DSSS instead of a GPL.

Signalling links are normally provided to the DSSS as a single pair, but unlike the signalling link sets in the national network, these are operated in a main and standby mode as the means of security.

† The DSSS will be the subject of a future article in the *Journal*

Group Processing Logic

The group processing logic (GPL) handles messages between central tram and its signalling terminals (STs). In the outgoing direction it receives messages from the MRP via the DIO and central tram, and is able to store a number of messages for each ST for retransmission purposes. Each message is allocated a new sequence number according to its ST, and a copy of the message transferred when the ST is ready to accept it. The message is deleted when acknowledged as correct, or retransmitted when requested.

In the incoming direction, the GPL receives messages from the STs. Each message has the validity of its sequence number checked and, if correct, the message is transferred to the MDP via the central tram and the DIO. Acknowledgement information is transferred for transmission in messages in the outgoing direction.

The GPL also monitors the status of all the STs. Any failures are reported to the management process.

Security

All data transferred between the PU and the STs has various checks performed on it at different stages in the transfer. In addition, test messages may be sent. These checks enable fault conditions in the hardware to be detected and fault reports to be sent to the MP.

Security against failures is provided by duplication of hardware. The central trams are provided in pairs, the number of pairs being dependent on the traffic requirements. As shown in Fig. 4, each GPL is connected to two central trams which are operated in a worker/standby mode. Thus, a signalling link set with links from two group terminal units (GTUs) is secured against a hardware failure.

CONCLUSIONS

An outline of common-channel signalling for System X has been given in this article in terms of the message-transfer part of the CCITT Signalling System No. 7 specification, the general network requirements, and its implementation using the message transmission subsystem.

The provision of CCS between digital exchanges, with its rapid and wide ranging signalling capabilities, will enable calls to be established quickly and reliably and new facilities to be provided.

It will also enable management facilities at the local administration centres, such that many of the functions of management and maintenance of the network, and the provision of new facilities as requested, can be carried out more efficiently from central points.

ACKNOWLEDGEMENTS

The author wishes to thank his colleagues in the BPO and STC Ltd. for their contributions to the development of common-channel signalling for System X.

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A New Equipment Practice for Exchange Switching Equipment and other Applications: Tep–1H

D. G. W. HARVEY†

UDC 621.395.345

The British Post Office, in conjunction with its main equipment suppliers, has introduced a new equipment practice to house the range of digital-switched exchanges known as System X. The equipment practice, designated Tep–1H, has other applications and can be used for the mounting of electronic equipment associated with earlier designs of exchange plant.

INTRODUCTION

The equipment practice used for electronic exchanges differs greatly from that used for Strowger and crossbar exchanges. There is no longer the need to provide a rugged steel framework to support the considerable weight of electro-mechanical selectors and conventional relay-sets. The first electronic exchanges in the British Post Office (BPO) telephone network used an equipment practice in which the racks were designed by the individual contractors. As a consequence, two versions of equipment rack emerged: one manufactured in aluminium, and one in steel. These designs were later used as the basis for the BPO documented T10000 and T10001 equipment practices, which are used in the manufacture of TXE2, 4 and 4A exchanges.

During the last decade great strides have been made within the BPO towards the realization of an integrated network of digital transmission and switching systems. At the heart of this system will be a new family of exchanges, known as *System X*, which makes extensive use of microelectronic technology. To secure rationalization of design, development and production, the BPO has collaborated with its main switching equipment suppliers in the design of System X; one feature of which is the adoption of a standard equipment practice, known as *Tep–1H*.

DESIGN OBJECTIVES

The design objectives of a new equipment practice were established in 1972. At that time, it was hoped that there would be a high degree of commonality between the equipment practices used for switching and transmission systems. The objectives were as follows:

(*a*) The new form of construction would possess all the features of accessability for cabling, flexibility, maintenance facilities and reliability possessed by the existing practices.

(*b*) The new practice could be completely different in concept from the existing forms of construction but it had to be compatible with existing designs from a station planning point of view.

(*c*) There was no need for an arbitrary distinction between transmission, data and switching equipment. The new practice could be designed specifically for digital equipment of all types; the existing forms of construction would continue to serve for analogue systems.

(*d*) Any new equipment practice would be agreed by all the BPO's major contractors and it would be possible for any manufacturer to supply the BPO and other UK and overseas customers without restrictions.

(*e*) There would be interchangeability of items made by different manufacturers down to the slide-in-unit level.

(*f*) Contractors would have maximum freedom to design electronic equipment down to slide-in-unit level in the most effective way consistent with the established standards.

(*g*) A new practice would, preferably, give a prospect of reduced cost per function, and have more facilities than existing forms of construction.

(*h*) The design and materials used would be consistent with the need for reliable operation over a long service life (that is, in excess of 25 years).

(*i*) The construction would be realized by simple manufacturing methods, have a minimum number of parts and be accurately reproduceable in mass production from basic materials.

(*j*) Enhanced capability to cope with high levels of power dissipation would be a prime requirement.

(*k*) Reliable connexion facilities would be provided between electronic modules and station wiring, catering for the increased number of functions provided within a unit volume.

(*l*) The design would meet the standard requirements of safety, including earthing.

(*m*) Attention would be paid to appearance and other external design features, bearing in mind the increase in provision of BPO electronic equipment in customers' premises and the desirability of avoiding special housings.

The compatibility hoped for between transmission and switching equipment practices to achieve a high level of commonality did not materialize. System X, at least for its earlier realization, required heavier slide-in units (SIUs), a higher concentration of cables and greater power dissipation than was necessary for transmission systems. Any one design of equipment practice was therefore likely to be uneconomic. The switching equipment practice satisfying the above has been designated *Tep–1H*, and the resulting design of transmission equipment practice *Tep–1E*, which has been described in the *Journal**.

MATERIALS AND FINISHES

Rack frameworks and piece parts are made of steel pressings or stampings, the materials are to BS 1449 (1972) Parts 1 or 2.

SIU guides and shelf mountings are moulded from thermoplastic material.

Normally visible parts (for example, rack footings) are painted. Rack side members which are not seen are zinc-plated and passivated. Covers for front, rear and ends are of plastic-coated aluminium. A view of an isolated

† System Evolution and Standards Department, Telecommunications Headquarters

* CRUMP, N. G. A New Equipment Practice for Transmission and other Applications: TEP–1(E), *POEEJ*, Vol. 72, p. 160, Oct. 1979.

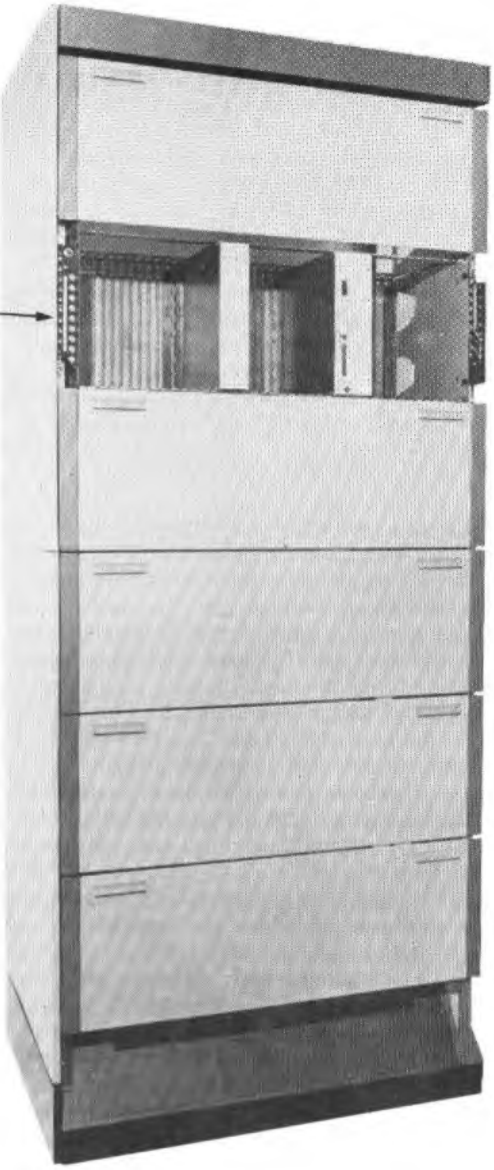

FIG. 1—An equipped and clad rack

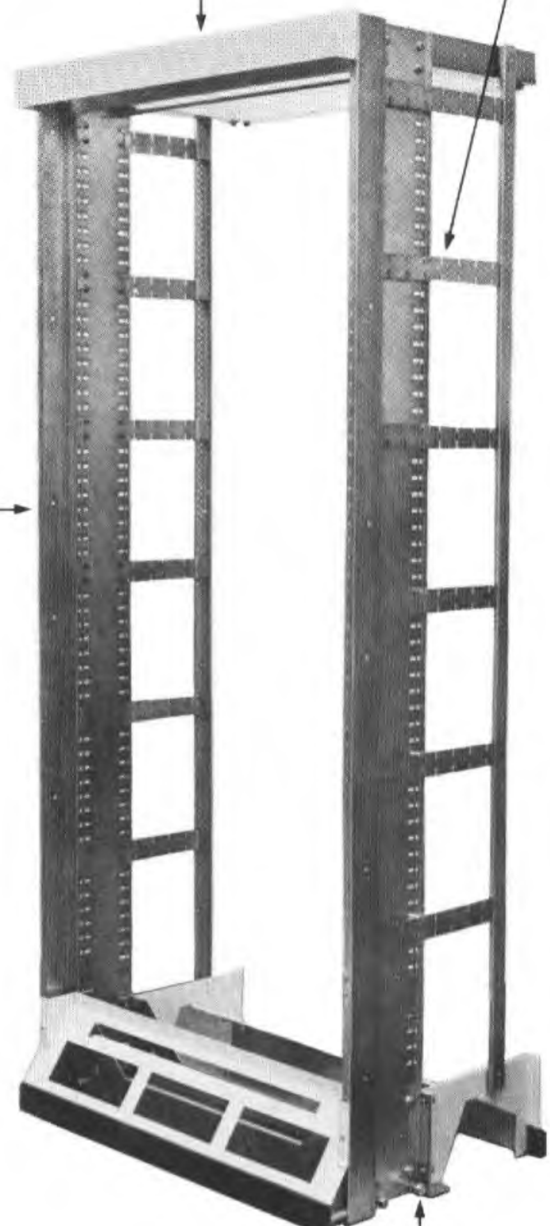

FIG. 2—Rack framework

rack complete with end-of-suite cover and with one shelf cover removed is shown in Fig. 1.

RACK

The rack side members are formed from mild steel to give adequate strength and provide channels for inter-rack and power cabling. The top load-bearing cross-member is a U-shaped section and the front and rear base members are angle sections bolted to the side members. Two spacing bars of 16 mm diameter mild steel are provided at the top and at the bottom of the rack between the side members. The bottom spacing bars serve also to maintain correct spacing between racks in a suite by use of pitching studs screwed to the ends of the bars. This is necessary where no spacer is provided between racks and could occur in very lightly cabled installations. Auxiliary uprights at the rear of the rack provide the frame on which rear covers are fitted.

The side members are pierced at intervals of 30·48 mm to fix the shelf guides and cable bearers, and to permit variation of shelf position if required.

The assembled framework, together with part of the cable support system is shown in Fig. 2. A view showing details of the rack base construction is shown in Fig. 3.

DIMENSIONS OF RACK

The nominal overall dimensions of the Tep-1H equipment rack are:

depth	630 mm (a 520 mm version has also been documented),
width	900 mm, and
height	2164 mm (other heights are obtainable in steps of 30·48 mm).

The equipment has been designed to house SIUs (planar printed-wiring boards (PWBs) or framed units) which are 285 mm high by 345 mm or 457 mm in depth. (The 457 mm unit can only be housed in the 630 mm deep rack.)

FIG. 3—Rack base

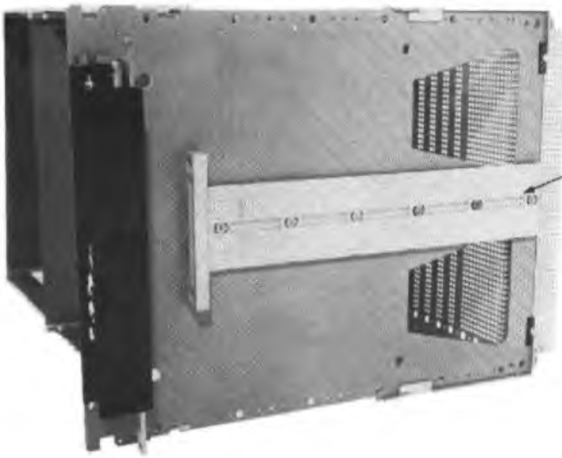

FIG. 5—Side view of shelf showing side plate and slide

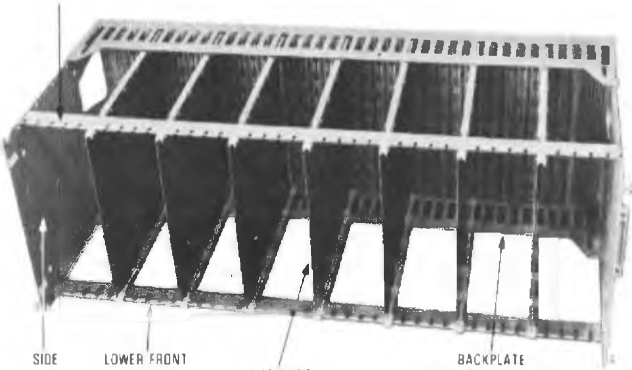

FIG. 4—Front view of shelf

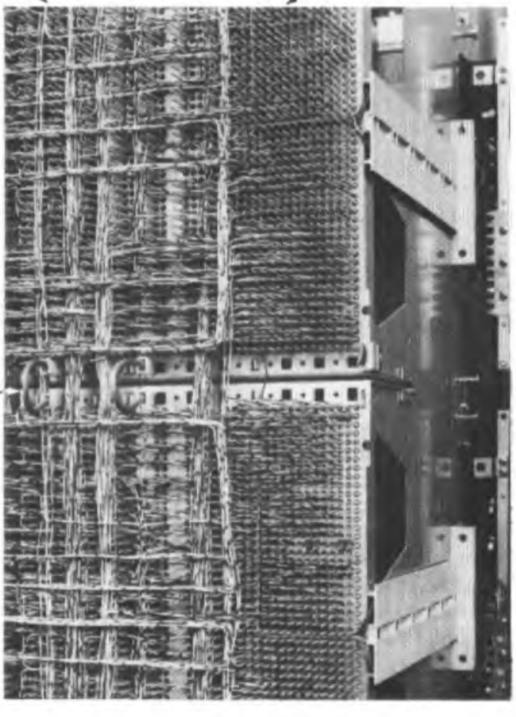

FIG. 6—Wiring of double shelf

SHELVES

The design of the shelves for Tep-1H has departed from that of the traditional shelf, which is supported at the front and is rigidly fixed to the rear members of the rack. As shown in Fig. 4, the backplate is bent at right angles top and bottom to give rigidity; the shelf side plates are secured by twisted tabs to the shelf backplate. The top and bottom front rails are of light metal construction and serve merely as a locating point for the card guidance system. The load imposed by the slide-in units is borne by aluminium membranes cantilevered from the backplate; these membranes are anodized to insulate the metal from the component leads on the rear of the adjacent slide-in unit. The shelf unit is secured to the rack side plates by means of a plastic slide (bolted to the sideplates), see Fig. 5, engaging with a mating guide fixed to the rack, see Fig. 3, and locked with screws.

In addition to the single shelf described above, shown as a shell in Fig. 4, double and triple shelves are also available. The double shelf has a one-piece double depth of sideplate on each side, onto which are mounted 2 single backplate assemblies. The double shelf is also equipped with 2 sets of plastic slides on each sideplate. A rear view of a fully wired double shelf showing these features is shown in Fig. 6.

The triple shelf has one-piece triple height sideplates onto which are mounted 3 single backplate assemblies. This triple shelf is equipped with 3 sets of plastic slides on each sideplate, but the rack is only equipped with 2 sets of mating guides in the 2 top positions. (Note: 3 slides are provided as they incorporate protection for the distribution wiring from the shelf fuse box.) All 3 sizes of shelves are therefore assembled to the rack as an entity.

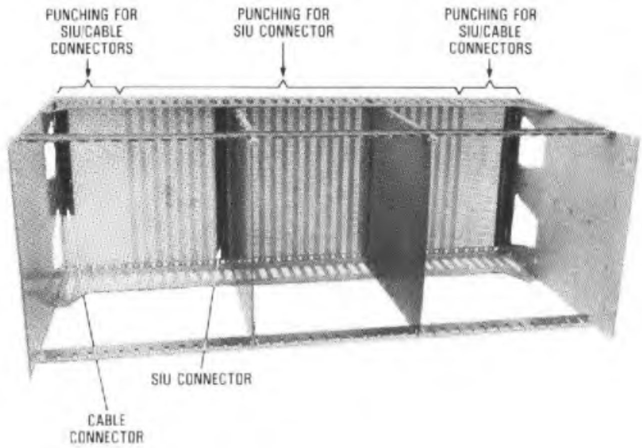

FIG. 7—Backplate and side plates

BACKPLATE AND SLIDE-IN-UNIT SUPPORT

For use with a 5·08 mm connector design, the backplate extends the full width of the shelf and accommodates cable connectors and connectors for slide-in units. Twenty-two rows of holes are punched at 5·08 mm spacing at each end of the backplate for cable or SIU connectors. The space in between is punched to accept connectors for SIUs at 20·32 mm pitch. The backplate and side plate construction detail is shown in Fig. 7.

A maximum of 40 planar cards can be fitted if no cable connectors are required (that is, when this shelf is part of a double or triple shelf and one of the other shelves carries the cable connectors). In this case, supporting membranes are provided on the basis of 8 per 40 planar cards and the membranes are distributed evenly along the shelf; when heavy slide-in units are provided, the position of the membranes is varied to give maximum support where needed.

The use of the cantilever method ensures that the SIU supporting system and the backplate are firmly fixed in relation to one another, hence any distortion of the shelf has no effect on the relative position of a SIU to its socket.

Where multiple shelf groups are used the individual backplates are bonded together electrically, as shown in Fig. 6, which also shows the typical wiring of a Tep-1H rack including the connexions to the cable connector field at the right-hand side. The accuracy of the pin placement permits the use of automatic wire-wrapping practices for the termination of cables.

A different type of backplate is used in association with the 2·54 mm connector design, which can be mounted on plain or multilayer backplanes (1, 2 or 3 sections) and assembled on the backplate. The suspension method for mounting SIUs is retained.

SLIDE-IN UNITS

Slide-in units can be single planar PWBs having integral edge connectors, framed units with discrete edge connectors or double units each with its own connector. The large units are capable of taking an auxiliary or daughter board.

Either depth of board can be housed in a 630 mm deep rack, but the 520 mm rack can only accommodate the shorter unit.

Slide-in units used for System X are equipped with front plates. These can have drillings and cut-outs to accommodate lamps, test points, etc. Each slide-in unit is fitted with a handle for ease of withdrawal. It is essential that some units are locked in position to prevent accidental removal, and a locking device, consisting of a spring loaded rod (see bottom right-hand corner of Fig. 8) extending from the front to the rear of the unit and operated from the front, can be provided. The rod screws into a plastic block attached to the backplate when required. Fig. 8 shows a heavy unit and includes the

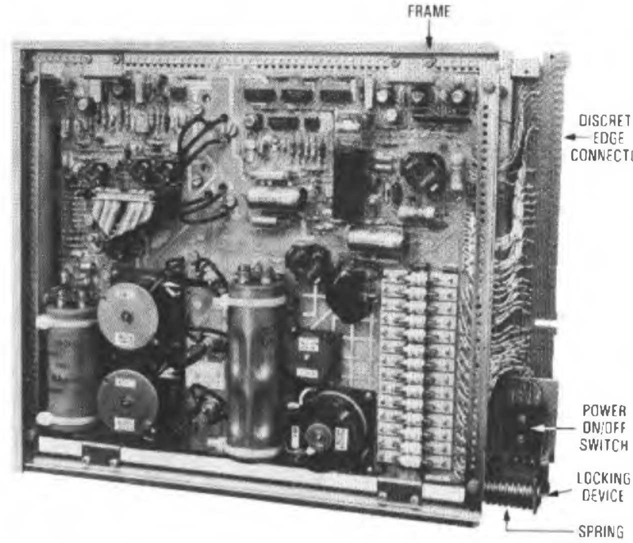

FIG. 8—A heavy slide-in unit

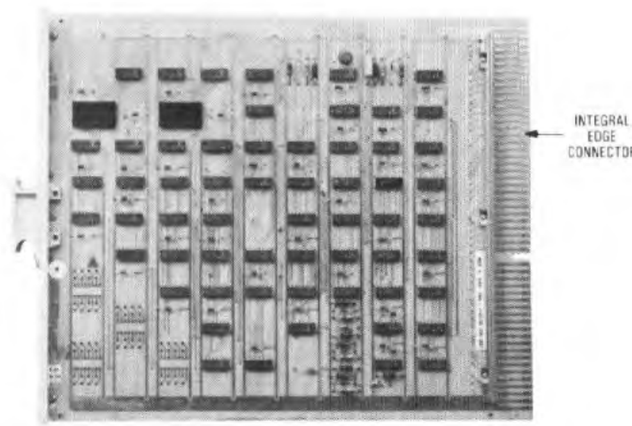

FIG. 9—A planar slide-in unit

framework, the discrete edge connector and a power ON/OFF switch associated with the lock. Early-make/late-break facilities can be provided by altering the length of the contact pad on the PWB. A view of a planar unit is shown in Fig. 9.

CONNECTORS

The connectors on Tep-1H have two main functions:

(*a*) to connect slide-in units to shelf wiring, or

(*b*) to terminate the cables entering the rack and connect these to the shelf wiring.

A 5·08 mm slide-in unit connector is shown in Fig. 10. The wiring pins protrude from the rear of the backplate, see Fig. 11, and the connectors are fixed securely by means of bosses in the moulding and retained by metal ferrules. Variations in contact formations within the connector can provide for special requirements; for example, bridging.

In the case of the cable connector, the male half is fixed to the backplate and pins protrude on either side to facilitate front or rear connexion as required. Cables between racks and between shelf groups within a rack are fitted with female connectors. This practice shortens installation time because the connectors are assembled to cables in the factory. These cable connectors can be attached either at

(*a*) the front of the backplate on the male cable connector pins,

(*b*) the rear of the backplate on the male cable connector pins (this is shown in Fig. 11 with the wiring omitted), or

(*c*) the rear of the backplate on the male SIU connector pins.

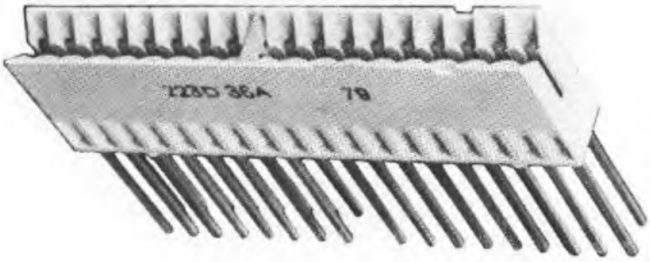

FIG. 10—A slide-in-unit connector (5·08 mm)

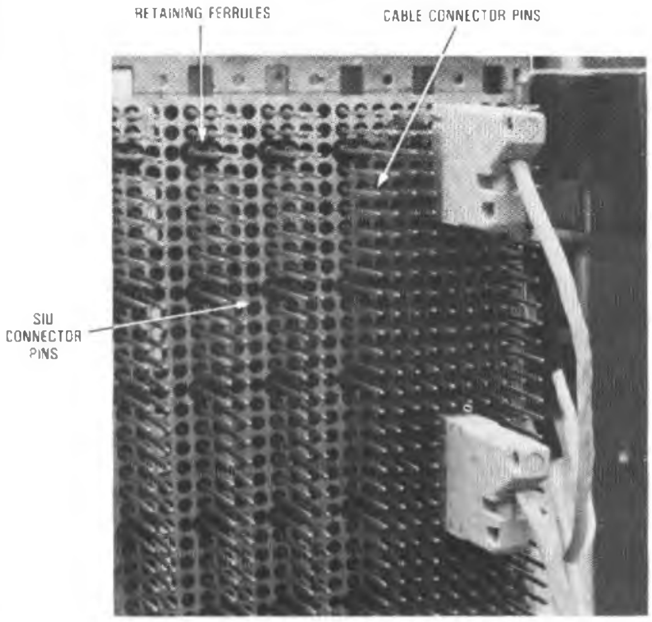

FIG. 11—Cable connector

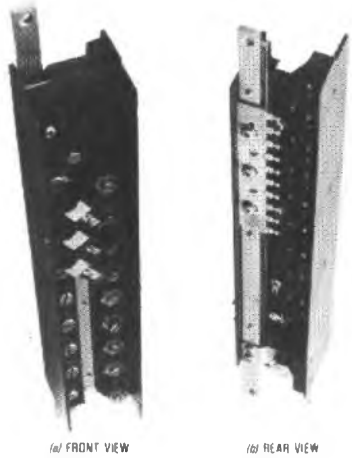

FIG. 12—Fuse mounting

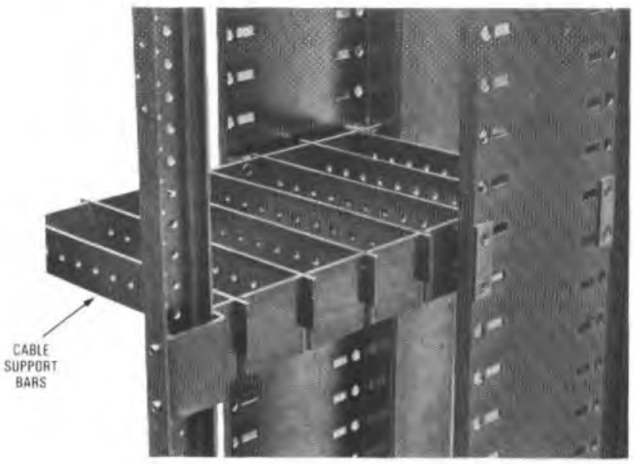

FIG. 13—Inter-rack spacing arrangement

To cater for greater component density and an increased number of input/output connexions, the 2·54 mm pitch connector has been introduced. This is a 96-way two-part connector with the male half attached to the backplane, the SIU therefore is not produced with an integral edge connector, but is equipped with the female half.

POWER SUPPLIES

The Tep–1H rack was originally designed for use with conventional bus-bars and, if required for use in exchanges having this method of power distribution, can still be supplied. For System X, however, a radial power distribution system is used with individual cables to racks or shelf units as required. Shelves, or parts thereof, are supplied through Type-44 fuses mounted on either side of the shelf, as shown in Fig. 1. A fuse mounting is shown in Fig. 12.

COOLING

Normally, racks are cooled by natural convection. For this purpose it is essential that the centre of the rack top is kept free from cables or any obstruction that might restrict the airflow from the top of the rack.

Where heat dissipation is exceptionally high, for example 2·5 kW, fan assisted ventilation can be provided.

CABLING

The Tep–1H racks are designed to butt together (see section on racks). The space formed between the side members and the space between adjacent shelf side plates is used for inter-rack cabling. This space suffices for the average density of cabling. However, the quantity of cable in many System X exchanges has necessitated increasing the cabling space by a further 150 mm (for exceptionally dense cabling this can be 300 mm). Vertical covers for cable spaces are provided.

A view of the inter rack spacing arrangement is shown in Fig. 13.

In System X exchanges, longitudinal cables are run in wire cable trays, which occupy positions above the front and rear of the rack; for transverse cables, a second layer of cable trays is provided.

The design of the rack is such that underfloor cabling similar to that in use in computer installations can be used. Also, some cabling can be at floor level using the space in the base of the rack.

CONCLUSION

The equipment practice described will house the new generation of telephone exchange switching equipment and will also perform the function of a general rack for those electronic equipments now in use in Strowger exchanges; for example, electronic call recording (metering) equipment.

ACKNOWLEDGEMENT

The author acknowledges the assistance of his colleagues in the BPO and members of the UK Telecommunication Industry who have contributed to the Tep–1H project and to the preparation of this article.

Monarch 120: A Central Installation-Workshop Facility

T. G. BRASSIL†

A new installation workshop has been set up in Bridgwater Supplies Depot to assemble, program and test the new British Post Office (BPO) designed digital PABX, which is being marketed as *Monarch 120*. The workshop, which is staffed and controlled by Taunton Telephone Area, started processing Monarch 120 systems earlier this year; eventually it will process about 1000 systems a year. Further growth in the demand for Monarch 120s will be catered for by the establishment of one or more similar workshops elsewhere in the UK.

Although at first sight the establishment of an installation workshop in Bridgwater Supplies Depot to serve the whole country may seem unusual, easy access to the M5 motorway, good accommodation and storage facilities, the availability of support facilities, and the willingness of local management to take on the project made Bridgwater an obvious site.

The workshop's involvement in the provision of Monarch 120s begins when an Area requisitions a unit by entering full details of the customer's requirements into a central computer via a terminal in the telephone area planning office. The computer generates an order and a complete stores list; it then processes the input to generate a machine-code database that will configure the Monarch 120 to match the customer's order. The workshop accesses the computer to extract the relevant job data, allocates a suitable date to begin processing the unit, checks that the necessary stores are available and then replies to the originating telephone area by Telex to confirm the order and delivery date.

Order processing usually starts about 3 weeks before installation, when the workshop transfers the database from the central computer into a custom-built programming device, known as the *automatic memory board loading equipment* (*AMBLE*). AMBLE is then used to insert the database into one of the Monarch 120 system memory boards which consist of eraseable programmable read-only memories (EPROMs); simultaneously it checks that the memory is operational and that it does not contain any data from a previous program. The unit is then switched on and tested to make sure that the main system is functioning.

The system, which should exactly match the customer's order, is placed in a hot room at an ambient temperature of about 30°C to soak-test the electronic components for a period of between 4 and 14 d; this helps to expose any potential failures in the system before it is installed in a customer's premises. During this time, the system maintenance and diagnostic routines built into the Monarch 120 ensure that it performs a complete self-test approximately every 2 h for the full system.

A few days before a unit is dispatched, the central computer is accessed again by workshop staff to see if the customer has made any last minute changes to his order; if he has, the new database is transferred into AMBLE and the EPROM board reprogrammed as before. The computer is then instructed to freeze any further alterations to the order until after the installation date. The system is then comprehensively tested and packed ready to be passed over to Supplies Division, which uses a fleet of vehicles that have been assigned specifically for the purpose of delivering the units directly to customers' premises on the day of installation.

The workshop provides an after-sales service, in the sense that staff offer help and advice to area staff on Monarch 120 installation matters, and provides on-site support with specialized test equipment to deal with particularly difficult installation problems. Apart from the normal provision of PABXs, the workshop also deals with the Monarch systems that are required occasionally for exhibitions and other functions.

† Taunton Telephone Area

Forthcoming Conferences

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Cardiff Cable Tunnel

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The growth of telephone traffic in the Cardiff telephone area has resulted in the construction of a large new telephone exchange building which is adjacent to the old telephone exchange. To optimize the provision of the network of underground cables serving the site, the British Post Office has built a tunnel system which radiates from the new exchange.

The construction of the tunnel, which has been a major civil engineering project, is described in this article.

INTRODUCTION

Since 1912 the telephone system in Cardiff has been centred on a site adjacent to the Welsh National rugby stadium. Originally, manual local and trunk exchanges were housed in the Head Post Office (HPO) building; later, on conversion to automatic working in 1952, the telephone exchange was housed in a building situated between the HPO and the river Taff. This latter building was equipped to maximum capacity by 1978 and plans for a further extension of equipment accommodation had been in hand for many years prior to that time.

This additional accommodation was designed as a 15-storey tower block—appropriately named *Stadium House*—which was built on a site vacated by the Postal Business on transfer of their mail-handling operations to a new building in another part of the city. This vacated site lay conveniently between the main HPO building and the existing automatic telephone exchange (ATE).

It was realized that, coincident with this major addition to the equipment accommodation, the underground network serving this increasingly complex site would also need to be developed if the potential of the site was to be exploited to the full.

After an assessment had been made of the likely cable capacity required and the obstructions which might be encountered in laying any substantial amount of surface duct, the British Post Office (BPO) decided to construct a tunnel system radiating from Stadium House to points at which conventional surface duct could connect to it.

PLANNING

Sir William Halcrow and Partners (Consulting Engineers to the BPO) were commissioned to undertake a feasibility study for a minimum length of tunnel which would overcome the difficulty of assuring adequate long-term access from all directions into Stadium House; they concluded that it was possible to construct such a tunnel at a depth of 15–20 m in the red mudstone, known as *Keuper marl*, which underlies Cardiff.

In planning the line of a tunnel system, two clear options present themselves. Firstly, the BPO can use the powers granted to it as a statutory undertaker under the provisions of the Public Utilities Street Works Act 1950 to drive a tunnel entirely beneath public highways. Although this course would virtually eliminate any problems regarding permission to build, it has two major disadvantages:

(*a*) the length of the tunnel would compare unfavourably with a direct routeing and result in additional costs, not only for tunnelling but for every cable installed in it, and

(*b*) any sharp turns encountered would make tunnel construction more complicated (and more expensive) for hand mining, and would completely rule out the use of any form of tunnelling shield.

The second option, which was adopted for the Cardiff project, is to plot as direct a line as possible, limiting any bends to a radius of not less than 150 m. This approach requires that private wayleave agreements are negotiated with each of the individual freeholders and leaseholders under whose properties the tunnel is to pass; such wayleave agreements need to be irrevocable. This direct-line approach was advocated by W. H. Lamb in his article on the London tunnels[1]. The difficulty with the direct-line approach is that one refusal to grant a wayleave can invalidate a complete routeing and force a designer to recommence negotiations for a revised line.

At the time that building work at the site of Stadium House was imminent, three shafts were sunk at the site because, although the construction of shafts below an existing building is possible, it would certainly have been a technically difficult and costly operation once the thick reinforced raft on which Stadium House was built had been cast. The basement of Stadium House is below the flood level and any breaching of the substructure after completion of the building would expose the basement, which houses the total energy power plant, to the risk of flooding.

The internal diameter of two of the shafts was 3·048 m and these shafts were destined to provide cabling access into the cable chamber of Stadium House. A third shaft, which was to emerge in a separate lift house, was 4·572 m in diameter and provided accommodation for a 5 t goods lift, access ladders and all the pumping and electrical services to the tunnel system.

The three shafts were sunk, caulked and capped by December 1973. The building of Stadium House commenced in 1974. Nine investigatory bore-holes were sunk at that time to a depth of about 20 m at various points along the general line of the proposed tunnel to supplement bore-hole information which was already available from other developers and undertakers.

The knowledge obtained from examination of the bore-hole samples did not guarantee that all was known about the structure of the ground because a bore-hole log can only reveal the soil structure that exists at a specific point and, while a succession of bore-holes telling a similar story gives an increasing degree of confidence, the unexpected can still lie between the bore holes to trap the overconfident. Nevertheless, with this soil information to hand, tunnel lining design was considered and a firmer indication of cost given.

In March 1975, seven contractors submitted tenders and, with inflation running at record levels, a cost variation mechanism was included in the contract. This mechanism, known as the *Baxter formula*, required each tenderer to include in his submission an evaluation of the percentage make-up of the contract in terms of labour, plant, cement, fuel, steel, etc., and once this make-up had been agreed it served as the basis for cost variation calculations. The Depart-

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† Planning and Works Division, Wales and the Marches Telecommunications Board

ment of the Environment publish each month an index for each of these items, related to a base index of 100 in 1970, which shows how costs have moved. From these indices and, the agreed percentage make-up, a fluctuation factor was calculated which was applied to the value of the work (at contract date value) which had been done during a given month.

CIVIL ENGINEERING

The successful tenderer (Sir Robert McAlpine Ltd.) moved on to site in August 1976 with an engineering team from the consultants, Sir William Halcrow and Partners, who were to supervise the construction on behalf of the BPO. The main work site at the eastern extremity of the tunnel scheme was on part of a shoppers' car park, adjacent to which was a vacant building that belonged to the Cardiff City Council; the Council leased this building to the tunnelling contractor for use as site offices, stores and workshops.

Shaft Sinking

In collaboration with the South Glamorgan Highway engineers, the first task was to fix the position of the work shaft centre because the entrances to the manhole which was built over the shaft were in the footway of a section of the Cardiff inner ring road, which at that time existed only as a plan.

The bore-hole reports gave a guide as to what could be expected when shaft sinking started. The bore hole nearest to the initial shaft showed 2·25 m of made ground overlying 0·5 m of soft brown sandy clay, beneath which was 4·25 m of brown and grey gravel with cobbles and some sand and clay. Below this level, under a 1 m thick layer of stiff red clay, was the Keuper marl in which the tunnel was driven. This marl continued beyond the limit of the bore-hole at a depth of 23 m below the surface. An illustration of the ground structure is given in Fig. 1.

In the ground above the clay layer the shafts were lined with cast-iron segmental rings, most of which were supplied second hand by the BPO and refurbished on site before sinking started. Once the shafts entered the marl the lining material was changed to reinforced concrete segments, which are considerably cheaper than cast iron. The whole of the tunnel was constructed of similarly designed concrete segments.

The method of construction used for the 6 shafts was as follows.

A hole was excavated, deep enough and large enough to bury 3 rings. The lowest of these 3 rings was then built; great care was taken to ensure that it was absolutely circular about the agreed centre point and that it was completely level. (See Fig. 2(a)). This ring was aligned so that a line from the centre point along the proposed line of the tunnel exactly bisected the key (that is, the very narrow segment which is the last piece installed to form a ring).

Two more rings were added above the first ring and the whole structure was bolted-up solidly. Each segment was manufactured with a grouting hole in it and through each of these holes a reinforcing bar was driven into the surrounding ground. (See Fig. 2(b)). The gap between the rings and the surrounding ground was then backfilled with concrete. (See Fig. 2(c)).

Thus, a solid collar had been formed below which the shaft was excavated and lined ring by ring, each lining ring was hung beneath its predecessor (see Fig. 2(d)); the two additional rings at the top acted as guard rings to prevent the

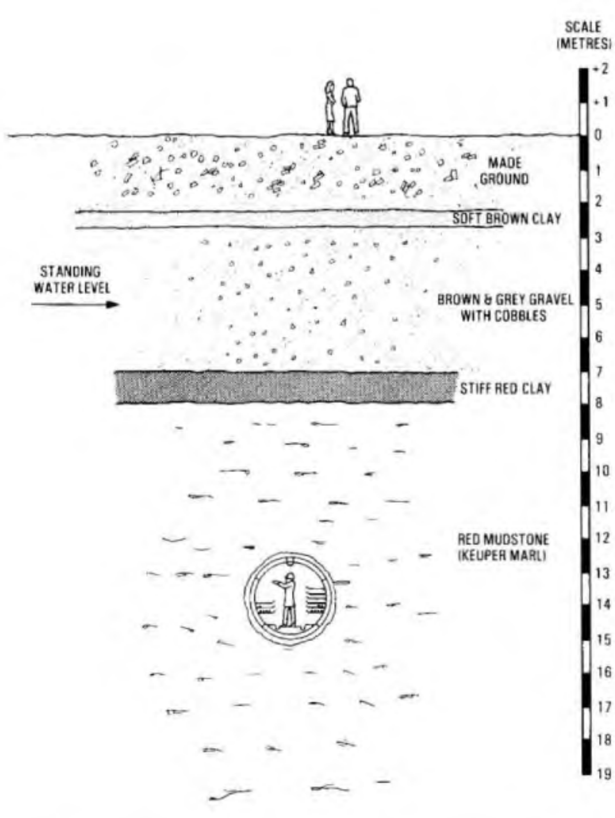
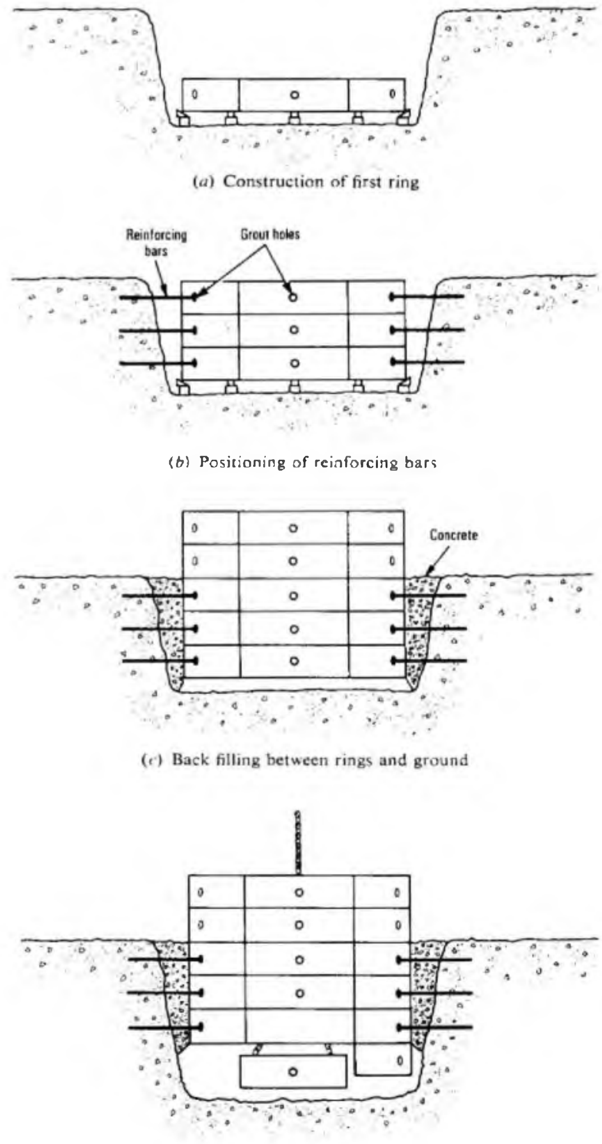


FIG. 1—Ground cross-section as revealed by a typical bore-hole at the Cardiff site



(*a*) Construction of first ring

(*b*) Positioning of reinforcing bars

(*c*) Back filling between rings and ground

(*d*) Placing of additional rings

FIG. 2—Stages in shaft sinking

unwary falling in. As the shaft sinking proceeded, the extrados (that is, the overbreak between the outside of the lining and the excavation) was filled under pressure with cement grout.

Water Problems

Ground water was first encountered at a depth of 4·5 m. However, the sinking of the work shaft proceeded uneventfully until the excavation was well into the marl. But, on 7 October 1976, at ring 29, the rate of water inflow through the bottom of the excavation suddenly increased dramatically and it was soon clear that the pumps on site could not cope, and the shaft was allowed to flood.

The tunnel had been designed originally with the lowest point in the system being at the work shaft for the practical reasons that

(*a*) any water encountered during tunnelling would drain downhill to the shaft, from which it could be readily pumped, and

(*b*) the skips of spoil would also be moved from the work-face with the partial aid of gravity, rather than being hauled uphill.

However, the inflow of water from an aquifer at tunnel level forced a revision of the plan. The alternative was to continue as planned using larger pumps and then construct the tunnel in compressed air at a pressure in excess of 138 kPa†, for which there was no provision or price in the Bill of Quantities.

The course adopted, which the consultant recommended, was to reverse the gradient between the work shaft and Stadium House so that the tunnel remained above this major source of water. This move reduced the effective depth of the work shaft by some 4 m and resulted in permanent pumping equipment being sited at Stadium House lift shaft. The gradient throughout the tunnel is nominally 1 in 250 downhill to the lift shaft.

The immediate task at the time was to stop-off the source of water so that the shaft could be drained; this was achieved by laying a 1 m thick plug of concrete at the bottom of the shaft.

Preparations for Tunnelling

The next part of the work consisted of building an enlargement of 4·572 m diameter in which the McAlpine tunnelling machine could be assembled. With the experience of the water flows encountered during shaft sinking in mind, the consultants advised that the ground in which this enlargement was to be built should be stabilised by pumping grout down pipes from the surface to fill any water bearing fissures in the marl. About 30 holes were sunk to tunnel level from the surface and some 50 t of grout injected.

The enlargement for the tunnelling machine was built without any great difficulty, but as excavation proceeded it became increasingly apparent how large were the fissures in the marl which the grouting had filled, and how much water lay in the ground. At that time, the contractor was reluctant to commit the tunnelling machine to the ground ahead without the safeguard of being able to pressurize the workings immediately if circumstances demanded such action. The contractor therefore proceeded, at his own expense, and with the consultant's consent, to drive a further 21 m of tunnel (3·048 m diameter) in which the tunnelling machine could be assembled and commissioned, and behind which an airlock could be built in the 4·572 m diameter section. This extra 21 m length of tunnel was reduced to a diameter of 2·438 m before it was handed over to the BPO.

Even at that stage of the project, a decision to work in compressed air had not finally been made but, as was called for in the specification, all the support plant for such operations had been installed and tested.

Compressors were housed in the basement of the leased surface-building to provide low-pressure air for pressurizing the workings and high-pressure air for powering air tools. Air receivers and filters ensured that an even supply of cleaned air was available to the workings. A medical air lock was brought to site to cater for the treatment of possible cases of decompression sickness, better known as the *bends*.

At this stage of the proceedings the tunnelling machine arrived on site. The function of the tunnelling machine (see Fig. 3) was to cut a 2·8 m hole through the ground, provide for the removal of the spoil it cut, and allow for the lining and grouting of the tunnel.

The tunnelling machine consisted of a digger shield, which was 3·6 m long and weighed about 28 t, the face of which was equipped with cutting teeth which revolved (see Fig. 4). The whole device was pushed forwards by 12 hydraulic rams acting against the last concrete ring to have been built. By choosing which rams were activated, the machine could be steered in both horizontal and vertical planes. (See Fig. 5).

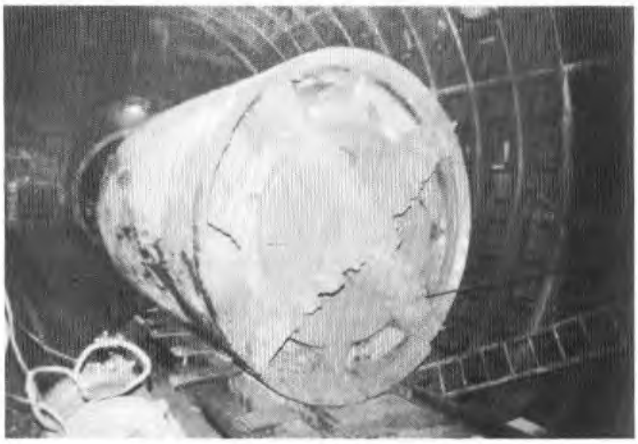


Fig. 4—Digger shield (at the end of its drive) showing the cutting face

(Photograph by courtesy of Mr R. Moorby of Sir Robert McAlpine & Sons Ltd.)

† Equivalent to 20 pounds per square inch (PSI).

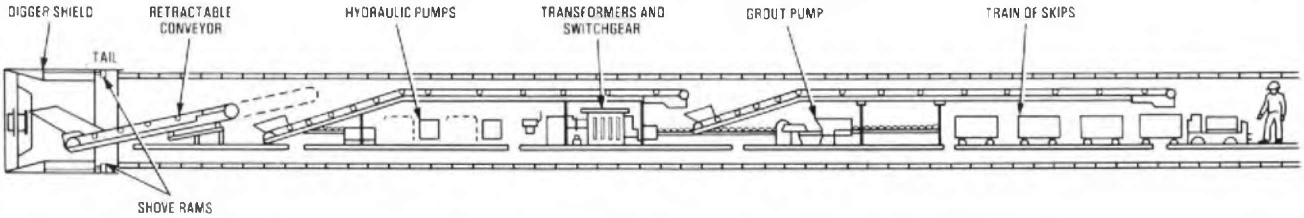


Fig. 3—Sectional drawing of the Sir Robert McAlpine full-face tunnelling machine

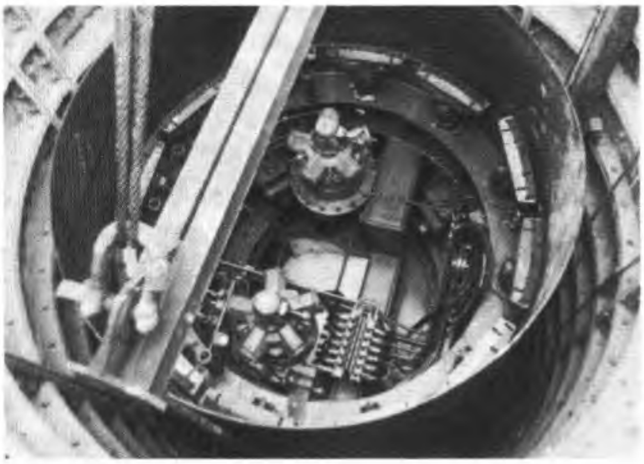


FIG. 5—Rear view of the digger shield being lowered into the tunnel at the work site (the two hydraulic motors and the shove rams can be seen)

(Photograph by courtesy of Mr R. Moorby of Sir Robert McAlpine & Sons Ltd.)

The shield dragged behind it a series of sledges which carried the necessary support equipment; for example, hydraulic pumps, transformers and electrical switchgear, grout pump and cement loading platform. Situated above the support equipment was a series of conveyors which fed the cut marl to a train of 1 m^3 skips, and down the side of the tunnelling machine was a roller conveyor which took the concrete lining segments forward to the front of the machine for erection. Each time the machine drove forward 0·610 m the rams were retracted and an additional ring was manhandled into position, segment by segment (each one weighed 250 kg), within the protection given by the tail of the machine; the key segment was the last unit to be placed in position.

Each ring of tunnel lining is made up of O-type and T-type segments and a key segment. The O-type segments form the part of the ring opposite to the key segment, which is flanked by two T-type segments. An O-type segment is angularly equivalent to a T-type segment plus half a key segment; that is, the circumference of a ring appears as a multiple of O-type segments. In this way, the bolt holes between adjacent rings are aligned even if the adjacent rings are built without the keys corresponding. This procedure, known as *rolling the tunnel*, produces a similar effect to the bond in brickwork in that the lateral joints are not aligned.

Compressed-Air Working

While the tunnelling machine was being installed, the probability of having to work in an atmosphere of compressed air was examined and, eventually, the contractor and the consultant concluded that, at least for the initial stages of the work, it would be necessary to use compressed air. The principle applied was that by maintaining an air pressure within the tunnel workings that balanced the pressure exerted by the head of water above the workings, the water inflow would cease.

An air lock similar in appearance to a large boiler was assembled behind the tunnelling machine, the necessary services (for example, power, water, air, telephone, etc.) were led through the bulkhead and, most important, the workers and engineers who would be employed in compressed air were given a thorough medical examination by the Medical Advisory Service of the Health and Safety Executive; those who passed the medical were issued with a *blue book*, which must be held by any person needing to go into a compressed-air environment. These medical checks had to be repeated at 6-monthly intervals for as long as compressed-air working continued.

The pressure which was used in the Cardiff tunnel was about 1 bar (97 kPa (14 PSI) above atmospheric pressure), which is equivalent to a head of water of about 10 m. Compressed-air working brings with it problems in two fields: medical and logistic. The one which attracts most publicity is decompression sickness—the *bends*—or, its minor form, the *niggles*. In a compressed-air environment, the bloodstream can absorb nitrogen in larger than normal quantities dependent on the length of time spent in compression and on the degree of compression. For example, at the end of a full shift spent at a pressure of 276 kPa (40 PSI) the bloodstream might be carrying a 1 litre excess of nitrogen. A problem occurs on decompression when the bloodstream is no longer capable of retaining this level of nitrogen. If decompression is too rapid this excess of nitrogen is released as bubbles in the bloodstream and, in any quantity, this can be fatal. To avoid this condition, the rate of decompression is related to working pressure and to the cumulative time spent in compressed air, and is codified in what are known as the *Blackpool tables*. At 97 kPa (14 PSI), major health problems do not usually arise, but some cases of the niggles (pains in the joints) did occur. The treatment for this condition is recompression of the sufferer in the medical lock to a pressure sufficient to clear the pain, usually somewhat above the working pressure, followed by an extended decompression period. In all instances in Cardiff, this type of treatment was sufficient without medical intervention.

From a practical point of view, the main penalty of compressed-air working was the need to pass all men and materials, ingoing and outgoing, through the air lock. This took time, and was restrictive because of the limited physical size of the air lock. Another penalty was the cost of keeping the works pressurized continuously 24 h/d. This entailed pumping in considerable quantities of air to make good the losses through the ground until such time as the caulking was complete.

Compressed-air working is, to some extent, a compromise. Air pressure within a tunnel acts uniformly in all directions throughout the length of the tunnel, but if the tunnel is constructed at a gradient and is of significant diameter (and in this instance 2·438 m was significant), the external pressure is not equal at all points. Thus, if the air pressure is sufficient to prevent any water inflow, there must be air escaping at points where the air pressure exceeds the external water pressure. Conversely, if the air pressure is adjusted for minimal air loss, then the pressure will be insufficient to exclude water at the lower levels.

Tunnelling

The tunnelling machine was used to drive a tunnel of 2·438 m diameter from the main work site to the northern end of the tunnel, a distance of some 1·1 km. In doing this, the tunnel passed through the area adjacent to Stadium House, where the tunnel was later enlarged to form the junctions to the three shafts which had previously been sunk. This enlargement will be used, when equipped with support steelwork, to direct cables from the cabling shafts to the section of tunnel through which they pass (see Fig. 6).

The tunnel drive to the northern end involved a right-angle turn, which could only be achieved by constructing a section of tunnel of 3·658 m in diameter in which to manoeuvre the digger shield. Fortunately, this enlargement was required for cable routeing purposes by the BPO.

The digger shield took some time to work up to its full potential due to a variety of factors: for example, it took the crew some time to learn how to steer the machine to the required tolerances, soft damp spoil stuck to the conveyors, harder material snapped off the steel cutting teeth (which had to be replaced with tungsten-carbide-tipped teeth). But eventually, the machine and its crew proved capable of excavating, lining and grouting over twelve 0·61 m rings in a shift; this rate of work enabled the tunnel to advance by about 15 m in a working day, with an average output of 6–7 rings per shift.

The usual cycle of operations was to excavate for one ring, build it, excavate for another ring and build that, then back grout the two rings. This cycle of operations governed the way in which the tunnel trains had to run. There had to be 4 skips ready to load with spoil for each one ring advance of the machine, and sufficient segments (loaded onto the roller conveyor in exactly the right order) and cement had to be on hand for the build-and-grout phases of the cycle. As the tunnelling machine advanced, the railway track had to be extended. Fortunately, the 2·438 m diameter tunnel was just large enough to allow for the occasional passing loop, and when mining was proceeding on two fronts at 600 m or more from the work shaft, the track and its 4 battery-operated electric locomotives were fully occupied. A view of a locomotive and skips is shown in Fig. 7.

By the very nature of its construction, the digger shield could not return along the tunnel which it had constructed unless it was cut up and removed in pieces. As the shield represented a considerable capital investment and it was required for another job, the machine was removed up the shaft at the northern extremity of the tunnel, and the various side tunnels, or *adits*, were excavated using hand tools. The short adits to the shafts at Stadium House were constructed directly without recourse to piloting once the good state of the ground had been established; a 300 m drive going west under the River Taff was built using a hand shield.

As with the digger shield, the hand shield consisted of a cylindrical metal skin inside the protection of which the excavation, lining and grouting of the tunnel was carried out by hand. This shield was pushed forward and steered by individually-controlled hydraulic rams. Production in the hand-driven part of the tunnel averaged between 3 and 4 rings per shift—a rate of advance of about 5 m per day.

In all the excavations, both tunnel and adits, the alignment was aided by the use of a laser beam. This fine beam of coherent light was used as a straight edge to convert what would be seen through a theodolite into a spot of light projected on to a target at the work face, thus enabling an operator to know immediately if his shield deviated from line in direction or elevation and take appropriate action as necessary.

When an enlargement, such as the turning enlargement or the main enlargement, was to be constructed on the line of a 2·438 m diameter drive, the tunnel was excavated and lined as normal to form a pilot tunnel, which was later 'broken up' to the larger tunnel size at a convenient time after the machine had gone on its way.

The method used to enlarge a section of tunnel depended to a great extent on the state of the ground. In poor ground, the work was completed in a number of small steps so that the size of the open face was kept to a minimum. The 2·438 m diameter tunnel was enlarged to a diameter of 3·048 m, ring by ring, and the chamber so formed was then enlarged to 3·658 m, ring by ring, and so on until the required diameter enlargement had been formed. In sound ground, such as that encountered in Cardiff, some or all of these intermediate steps could safely be omitted, with consequent saving of time and reduction of cost.

Each ring of tunnel is, to a large extent, a self supporting structure, but if a segment is removed then all stability is lost. So, before an adit or tunnel could be driven out of the side of an enlargement, the remaining segments of the affected rings had to be fully supported until such time as the junction between the enlargement and the adit was excavated and permanently supported by a steel lintel, which was held on two jambs with a steel sill between their feet. The whole of this type of structure was finally backfilled with concrete.

FIG. 6—The main enlargement (the west tunnel junction can be seen on the right-hand side of the photograph)

FIG. 7—Chamber at the foot of the work shaft with a train of skips leaving the air lock

(Photograph by courtesy of the *Western Mail*)

Waterproofing

The grouting which followed the building of the concrete rings was primarily intended to fill the extrados and prevent ground movement, rather than to act as a totally effective water-barrier. Once water had reached the outside surface of the concrete lining it passed into the joints between the segments of lining and, unless steps had been taken to prevent it, this water would have found its way into the tunnel through the joints and along the line of each of the fixing bolts.

The joints were sealed by filling the caulking groove (see Fig. 8) on the inside of the lining with a cement-based caulking

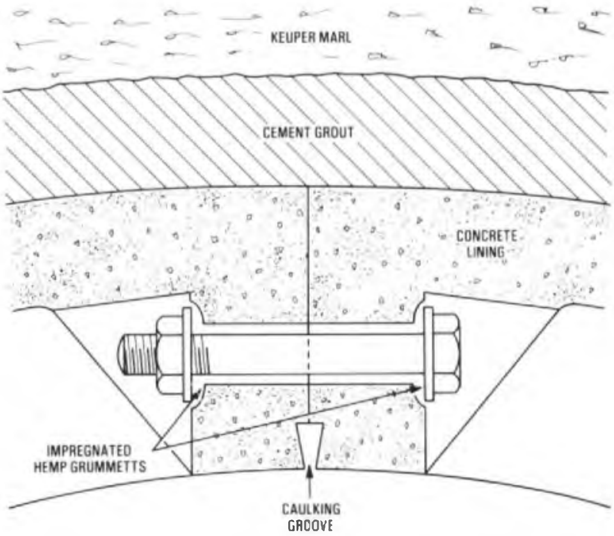


FIG. 8—Section of the lining illustrating the caulking method

filler, which was well compacted and which was overpainted with a waterproofing compound when the need arose. This type of compound, when used in conjunction with concrete or cement, percolates into it and then reacts with water to form a crystalline seal; the makers claim that it can penetrate 75–100 mm into concrete.

Each of the holes through which the fixing bolts pass were sealed by the inclusion of a pair of hemp grummetts, impregnated with silica grease, which were forced into recesses in the concrete behind steel washers.

FINISHING WORKS

Floors

A semicircular invert was clearly unsuitable as a permanent finish, so a concrete floor was laid (see Fig. 9) and, subsequently, covered with a granolithic layer, which received a sprinkling of carborundum dust where a non-slip surface was specified. In enlargements, this flooring is sensibly flat over the whole area with just sufficient fall to allow for necessary drainage but, in the 2·438 m diameter tunnels, the floor was profiled to allow for the inclusion of two drainage gullies and side benchings, which will act as guides for the cabling trolleys used for drawing cables into position.

Drainage

Although the BPO had called for a high standard of watertightness it would clearly have been unwise not to cater for the removal of water, therefore two pumps were provided in the sump of the lift shaft; the pumps have a total combined capability of lifting water to the surface at a rate of 546 litres/min. On completion of the 1·4 km length of tunnel the inflow of water was less than 23 litres/min. The two pumps normally do duty on a turn-and-turn-about basis under the control of steel electrode level detectors. If the inflow exceeds the capacity of one pump then both pumps are brought into use, and any further rise in the sump water-level raises an urgent alarm.

Toilet facilities have been provided; these include the usual offices, washing facilities, a sewerage pump, a small air conditioning fan and an electric water heater.

Ventilation

At the main enlargement each tunnel and the toilet adit contains a concrete cross bulkhead for ventilation control. Three of these bulkheads have a large fan housed in a duct above the door to draw air down the lift shaft and exhaust it through ventilators at the outlying ends of the system. The ventilation plant has been designed to produce between 2 and 3 air changes an hour. All the bulkheads are pierced by personnel doors and cabling ducts.

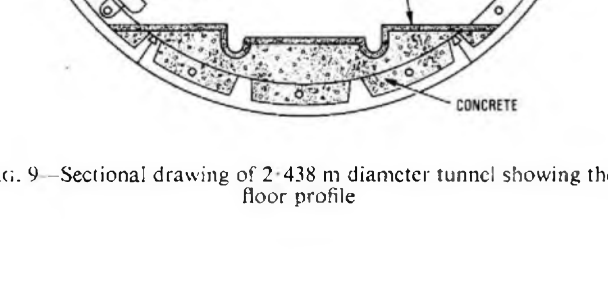


Fig. 9—Sectional drawing of 2·438 m diameter tunnel showing the floor profile

Surface Manholes

A two-part surface chamber was built at the top of each of the three remote cabling shafts, with the shaft emerging in one half and the surface duct leading away from the other half, the two halves being separated by a watertight bulkhead incorporating a watertight door and ducts closed with caulking glands.

Shaft Steelwork

The tunnelling contractor was responsible for erecting the steelwork in the 6 shafts. In the cabling shafts this consists of a series of platforms, at intervals of about 3 m, connected by sloping ladders. Tacking bars to support the cables are provided at every platform and at intermediate levels between platforms, thus the distance between adjacent sets of tacking bars does not exceed 1·5 m. In the lift shaft, the steelwork consists of a rectangular tower inside which the 5 t goods lift was installed by another contractor. Outside this mesh-guarded tower is a service bay, which accommodates various pumping and supply mains, ventilation ductwork and trunkings, and a ladder bay with regularly spaced platforms.

CONCLUSION

With the work sites cleared and reinstated and with the tunnel complete (except for the remedial works which are the contractor's responsibility during the 12 months following handover), the BPO and its sub-contractors have moved on site to provide the electrical services, ventilation plant, alarms, lift, telephones and cable support steelwork. (The reader's attention is drawn to other sources of information[2–4] regarding tunnelling projects.)

ACKNOWLEDGEMENTS

The Cardiff cable tunnel project has been the product of many people's efforts and enthusiasm, and the author gratefully acknowledges the assistance and encouragement of his many colleagues in the Cardiff Telephone Area, Wales and The Marches Telecommunications Board Headquarters, London Telecommunications Region and Telecommunications Headquarters. A special word of thanks must go to the staff of Sir William Halcrow and Partners who have patiently answered the author's numerous questions and afforded him an insight into the world of the tunneller.

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Regional Planning for Woodbridge System X Exchange

I. R. HILDREW, B.SC.†

INTRODUCTION

The first local System X exchange, at Woodbridge, is due to be brought into public service at the end of 1980. Woodbridge was selected as a suitable site because of its proximity to the British Post Office (BPO) Research Centre at Martlesham Heath, Ipswich, and the System X test-bed facility; it will thus assist the ongoing development and testing that is inevitable with the introduction of new technology.

The present 5000-line Strowger exchange is housed in an extended non-standard building; the System X equipment catering for 1000 lines is being accommodated within the existing apparatus room as the first phase of an ultimate complete replacement. Planning at Regional level, which commenced early in 1978, was necessarily confined to network connexion to and from the new exchange; the actual dimensioning was carried out by Telecommunications Headquarters (THQ) staff, from the traffic data provided by Colchester Telephone Area.

PLANNING CONSIDERATIONS

To limit the amount of signalling interworking subsystem/analogue line termination subsystem (SIS/ALTS) interface equipment, all incoming and outgoing traffic to the group switching centre (GSC) at Ipswich is carried on 30-channel pulse-code modulation (PCM) circuits. Because it was necessary to provide a large number of PCM circuits with security, problems were encountered with the selection of cables for the interceptions. Routes to the emergency and operator services are routed over 4-wire audio circuits; access to most other exchanges is gained via the Strowger portion of the exchange, since to do otherwise would have been uneconomic. The new PCM circuits enable the existing circuits to be left connected to the Strowger exchange so that, if the new exchange needs to be withdrawn from service for tests, the customers can be transferred back to the Strowger unit with the minimum of inconvenience. To achieve this change-over, relays are used to switch customers' lines and divert incoming traffic. Miscellaneous facilities, such as trunk offering, are similarly diverted. In order to achieve the partial replacement of Woodbridge, the Strowger exchange has been reconfigured for incoming traffic from Ipswich; this and other features are shown in Fig. 1.

Other planning activities have consisted of providing 2 cooling units for the System X floor area, and a DC distribution point for power to be fed to each rack by a radial distribution system; conductive flooring has also been laid throughout the digital exchange and control areas to reduce static electricity, which tends to be greater in the cooled dry atmosphere. Arrangements being finalized at present include the procedures for circuit line-up and subscribers' change-over.

ROUTEING CONSIDERATIONS

Metering of calls in the System X exchange is performed wholly within the local exchange; therefore code 0 routes with metering-over-junction (MOJ) facilities are not required, nor is a separate code 0 coinbox-telephone route needed. A number of register access relay-sets at Ipswich GSC have been modified and it is not necessary to connect these to the international call timers. Planning associated with the decoding of digits for routeing and charging information has already been completed; this involved decoding all area and international country codes so that the exchange could determine the correct charging rate.

SUPPLEMENTARY SERVICES

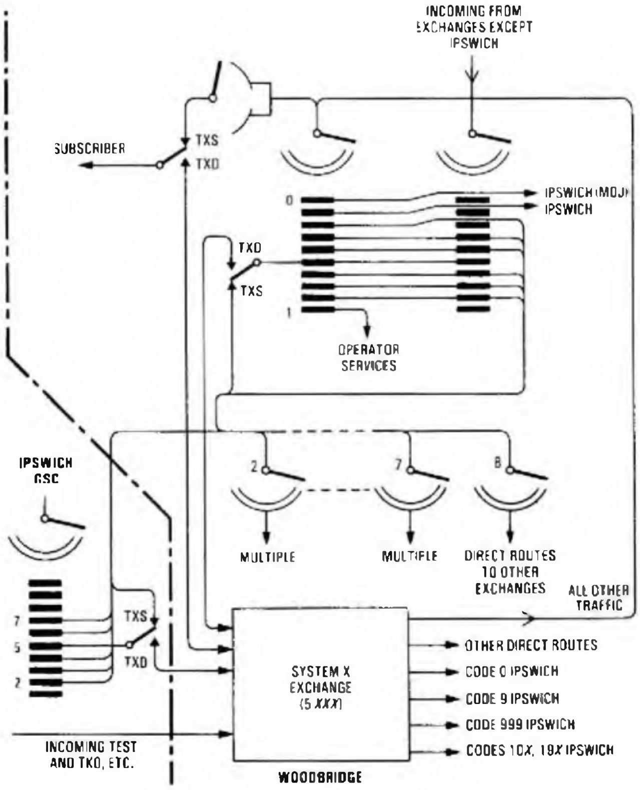
It is intended to hold a supplementary-services trial for about one half of the 1000 customers. They will be offered MF4 keyphones with register recall to enable them to use the services.

MAINTENANCE FACILITIES

Woodbridge digital exchange will initially not have an associated processor-backed local administration centre (LAC); however, a basic local servicing control unit will be provided on-site to assist in formulating maintenance procedures. The maintenance of the exchange will be undertaken by the staff who at present maintain the Strowger exchange.

CONCLUSIONS

As is to be expected with a new technology, the staff in the Region and Telephone Area offices are still learning and being guided by THQ; but much has already been learnt that will help in the introduction of other local System X exchanges throughout the country.



MOJ: Metering over junction
TXS: Strowger exchange
TXD: Digital exchange
GSC: Group switching centre
TKO: Trunk offering

FIG. 1—Woodbridge trunking arrangements

† Planning Division, Eastern Telecommunications Board Headquarters

British

TELECOM

Birth of a Business

M. McDONAGH†

In September 1979 the Government announced its intention to introduce legislation which will divide the British Post Office (BPO) into two independent corporations. The one which will run telecommunications and data processing will have the formal title *British Telecommunications*.

Although legislation will not go through Parliament until next year, preparations for the transition are well advanced so that already the telecommunications arm of the BPO is trading under the new name of *British Telecom*, for which a distinctive logo and associated 'T' symbol have been designed.

In accordance with the wish of the Industry Secretary, Sir Keith Joseph, the main changes in practical terms were substantially achieved by the middle of this year.

Short-term plans for re-identifying the mainstream aspects of the business using the *British Telecom* logo and 'T' symbol were announced by Mr. Peter Benton, Managing Director, British Telecom, in May at a small exhibition and demonstration at London's World Trade Centre.

The new identity, which introduces a second house colour—bright blue—to supplement the familiar yellow adopted for vehicles some years ago, will begin to appear progressively over the next few months. The cost will be spread over several years in line with normal replacement and refurbishing, and so it will not become a burden upon the business.

A number of leading industrial design groups was invited to submit proposals for the scheme. The winning submission is the work of Banks and Miles and was chosen by the former chairman of the BPO, Sir William Barlow; Mr. Peter Benton; Mr. Bryan Stanley, general secretary of the Post Office Engineering Union, representing the Council of Post Office Unions; and Lord Reilly, the former director of the Design Council.

† Features and Information Bureau, Central Headquarters

The new livery

Arrangements are well advanced for the phased application of the scheme and it is intended that all points of contact between the business and its 17 million customers will eventually adopt the new identity. For example, all 50 000 vehicles, ranging from the standard 7 cwt engineering van to heavy duty articulated lorries, and representing the biggest single-owner transport fleet in the country, will take on the new livery. About 8000 new vehicles, the normal annual replacement quota, will go into service in yellow and bright blue by the end of 1980 and existing vehicles will be treated as they become due for routine overhaul and repainting. (Almost all of the country's 61 telephone areas have at least one new-look vehicle in service today.)

Other items on which the new logo or symbol will progressively appear include some of the 63 million directories and dialling code booklets issued every year; the 65 million telephone bills; and the headed notepaper and other stationery used in the business at headquarters, regional and telephone area levels. The new identity is also being applied to jointer's tents, safety helmets and other equipment carried by engineers, and to new lapel badges for staff.

The Managing Director has said that the new identity would help to reinforce the importance of the 8-point plan recently introduced to meet booming demand and improve the quality of Britain's public telecommunications services.

The elements of this plan, which demand a £1500M a year investment between now and 1985 and a continued drive to the end of the decade, are as follows:

(*a*) A massive replacement and modernization programme for almost all of the 6000 exchanges in the UK public network and new products in the PABX field.

(*b*) A continuing programme to iron out troublespots in the local underground cable network. More than £42M would be spent on this work in 1980–81.

(*c*) Improving the reliability of the standard type 746 telephone handset by introducing new electronic microphones; £50M would be spent over the next four years.

(*d*) A major programme to replace public kiosk and renters' coinbox telephones with new improved designs giving added customer facilities. By the autumn of 1980, 400 new Blue Payphones are due to be in service and a total of £250M will be spent on the entire replacement and upgrading programme.

(*e*) A drive to keep international service provision ahead of the 20% annual call growth. Britain already has the most extensive international direct dialling service in the world, and efforts to improve operator services are beginning to show encouraging results.

(*f*) Speeding response to customers' needs by allocating total responsibility for tasks to individuals and reorganizing the business along commercial lines.

(*g*) Overhauling methods of buying-in and distributing equipment.

(*h*) Harnessing staff support for the drive to improve customer service. □

Protection Against Thames Flooding

R. HARPER†

Until the River Thames barrier project is completed, large areas of London remain at risk from flooding which could be of catastrophic proportions. The deep-level cable tunnels* within the London Telecommunications Region (LTR) were particularly vulnerable to the ingress of water. This fact prompted the LTR Works Division to make a detailed study of the possible effects of a major flood on this system.

The first consideration was, of course, the safety of personnel. This aspect presented little problem because the Greater London Council flood-warning control gives several hours advance notice of the build up of the factors which, in combination, will produce the flood condition. The present security procedures ensure that the number and whereabouts of personnel in the tunnel system are known, leaving plenty of time for their evacuation and for the closing of all bulkhead doors.

The next stage of the study was to locate the points at which water could enter, and to determine ways and means of effecting a seal. The examination showed the top of one 5 m diameter vertical cabling shaft to be 6·85 m below the predicted maximum flood level. This shaft is situated in the basement of a building in the vicinity of the River Thames and the shaft would certainly have been flooded in the very first stages of a tidal flood. This shaft gives access to a substantial length of horizontal tunnel before bulkheads, isolating the major part of the tunnel system, are reached.

Experiments had shown that hydraulic pressures, created by the head of water acting on the bottom of the shaft, would have been sufficient to crush air-spaced cables and allow water to enter the cable cores. Therefore, it was decided that the shaft should be sealed, provided that the work could be achieved at reasonable cost.

Sealing of the shaft with a flat or dome-shaped cap would have been fairly simple but for the presence of about 100 cables which pass through the basement of the building and down the shaft. The sealing of these cables presented the major problem. After considering various possibilities, the conclusion was reached that the only practicable solution was to extend the circular shaft segments to the ceiling of the basement, leaving an inlet in the circumference for a duct seal to accommodate the cables. The work was put in hand and a view of the completed installation is shown in Fig. 1. A bulkhead door was provided for access to the shaft.

A flat face was provided on the exterior of the circular shaft for the inclusion of a non-standard duct seal, which comprises Duct No. 54D, glands, lock nuts and end caps. The duct and glands had to be cut longitudinally and sprung over the cables. A Desoutter saw was used for the cutting process to minimize the amount of material removed from the split and to ensure that a split item returned to its original shape after being passed over the cable. The fitting of the ducts and glands around the cables was achieved using slit wideners manufactured by the LTR Power Workshop. A diagram of the duct seal construction is given in Fig. 2.

A cable gang was in attendance to open up the cable formation while the ducts and glands were fitted; the cables were lowered, layer by layer, as the shuttering was installed and the concrete placed. Reinforced lightweight concrete was used in the construction to reduce the load on the shaft structure to approximately two-thirds of what it would have been had conventional concrete been used.

The project was very much a team effort involving LTR external works, drawing office and power staff. The supervision of the construction work was undertaken by staff of the South Central Area, and the North Central Area provided the cable gang.

While there is every confidence that the measures taken will prove effective should the need arise, it is very much hoped that they will never be put to the test. □

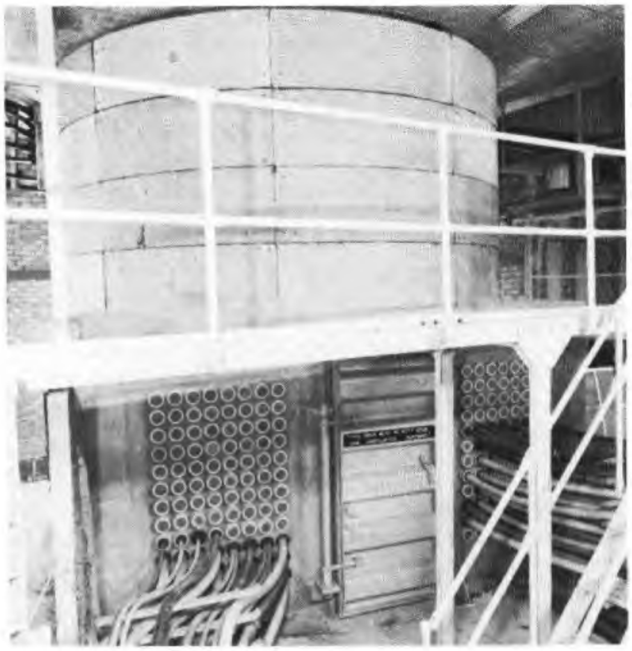
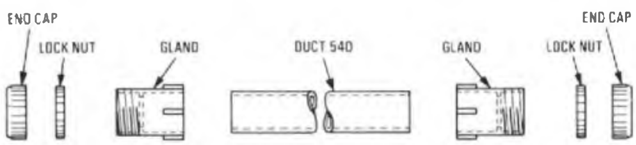
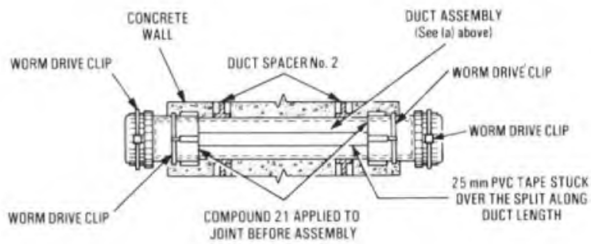


FIG. 1—Shaft extension and cable inlets



(*a*) Duct seal components



(*b*) Construction detail

FIG. 2—Diagram of duct seal arrangements

† Mr. Harper was in the LTR (Works Division) and is now in the Transmission Department of Telecommunications Headquarters

* LAMB, W. H. The London Cable-Tube System. *POEEJ*, Vol. 63, p. 14, Apr. 1970

An Improved Pseudo-Random Digital Sequence Error-Detector

F. L. ADAMS†

UDC 681.32:621.373:621.394.14

This article describes a method of detecting bit errors, irrespective of rate or burst pattern, in a pseudo-random digital sequence of pattern length $2^n - 1$ bits.

INTRODUCTION

The conventional pseudo-random digital generator (see Fig. 1) generates the required pattern by comparing the outputs of specific stages of a shift register in an EXCLUSIVE-OR gate and by feeding its output back into the input stage of the register. This produces a pseudo-random sequence of $2^n - 1$ bits (where n is the number of stages in the shift register). However, the $2^n - 1$ sequence is only generated if the correct outputs from the shift register are chosen; more than 2 outputs may be required for some values of n. A truth table for $n = 4$ is given in Fig. 2. For the sake of simplicity, only the 2-output case is considered in this article.

Although the present design of basic error-detector has features similar to the generator, it does not incorporate a locally-generated pattern (see Fig. 3). The feedback loop between the EXCLUSIVE-OR gate (G1) and the first stage of the register has been removed in the detector, and the incoming digital sequence is injected into the first stage of the register and clocked through it under the control of a clock signal. Subsequently, in a situation where no bit errors are present, the digital sequence input is identical to the output from the EXCLUSIVE-OR gate G1. These 2 signals, when compared in the second EXCLUSIVE-OR gate (G2), provide a *zero* state output. If there is an error in the digital input sequence, then at that instant the 2 inputs to gate G2 are different; this results in an output pulse which is gated with the clock signal in an AND gate (G3) to give singular error pulses; therefore adjacent bits in error can be individually detected. Any error in the digital sequence presented at the input to the register is clocked through the register and therefore appears at the outputs of x and nth stages. As a result, 3 output error pulses are produced for a single error in sequence; to overcome this problem a divide-by-3 circuit is added.

† Transmission Department, Telecommunications Headquarters

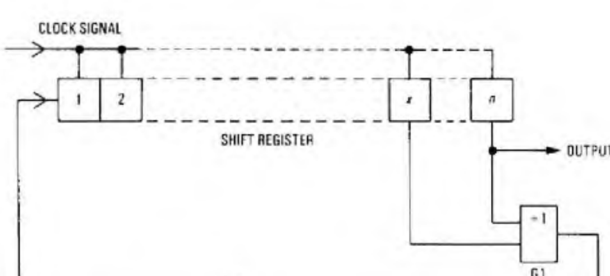


FIG. 1—Block diagram of a pseudo-random digital generator

1	1	0	0	0	1	0	0	1	1	0	1	0	1	1	1	1
2	1	1	0	0	0	1	0	0	1	1	0	1	0	1	1	1
3(x)	1	1	1	0	0	0	1	0	0	1	1	0	1	0	1	1
4(n)	1	1	1	1	0	0	0	1	0	0	1	1	0	1	0	1

FIG. 2—Truth table for $n = 4$

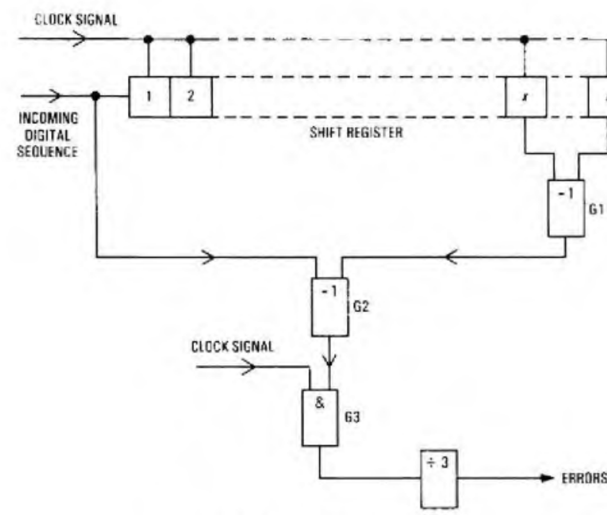


FIG. 3—Basic error-detector

AN IMPROVED ERROR-DETECTOR

With the conventional error-detector, the EXCLUSIVE-OR gates fail to provide an error output condition when errors occur in the x and nth stages simultaneously (which could be the case when errors occur in bursts) and this results in an inaccurate error count.

One way to overcome this problem is to arrange for the error in the digital sequence to be counted only once by using a bit-by-bit comparison technique. By this method a locally-generated pseudo-random signal is compared with the incoming digital sequence, but some form of synchronization is needed to lock the locally-generated signal with the incoming sequence. Therefore an alternative method of detecting errors has been developed to obviate the need for synchronization.

The basic circuit of the improved detector (see Fig. 4) includes a second shift-register (B) which is used to store the equivalent position of the bits in error; these are clocked through the register so that, if there is a bit in error in stage y of register A, a logic *one* state is present in stage y of register B. When the *one* state arrives at the output of stage x or n of register B, this condition is used to invert the outputs from stage x or n of register A, via gates G4 and G5, to produce an error-free output condition (that is, the bit in error has only been detected at the input stage). An example of the inversion process is given in Table 1.

TABLE 1
Example of Logic-State Inversion Process between Shift Registers A and B

Shift-register A:	Stage	1	..2	x	.... n
	Bit state	1	..0	........E	.... E
Shift-register B:	Stage	1	..2	x	.... n
	Bit state	0	..0	1	 1

E: Error bit

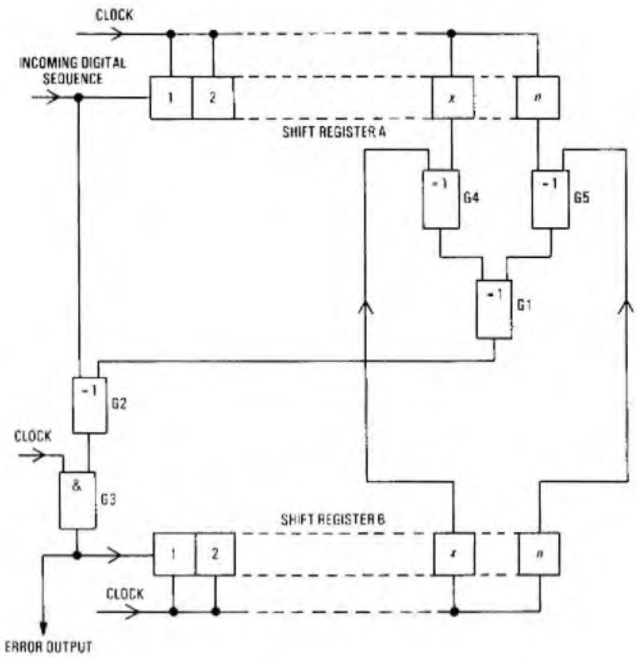


FIG. 4—Basic circuit of an improved error-detector

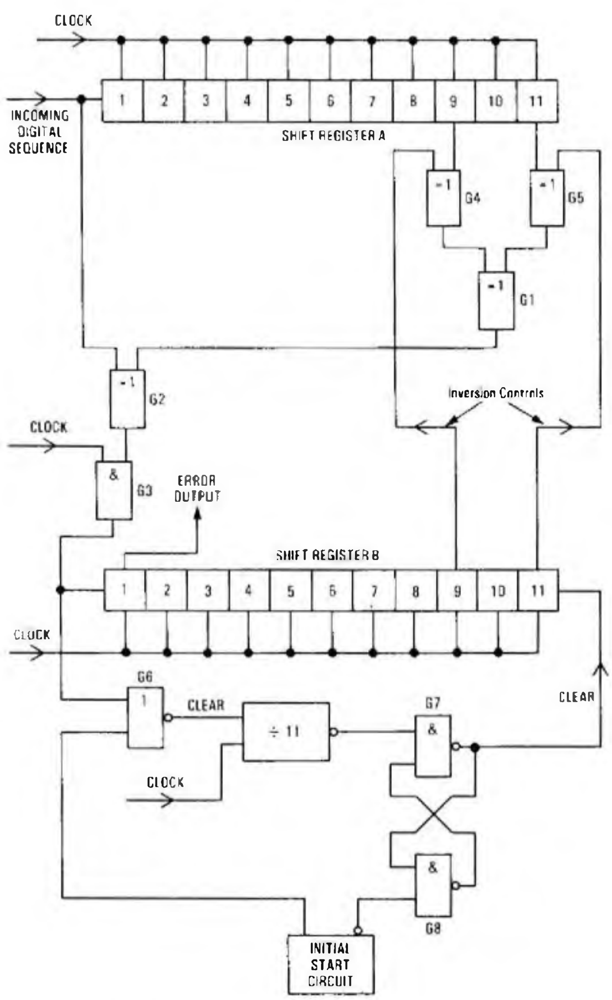


FIG. 5—Practical circuit of an improved error-detector

By using this method of error detection the divide by 3 circuit is not needed. However, this method only works in practice if register A is set initially in an error-free mode and register B set at zero, so some form of self-start mechanism is required to overcome this problem.

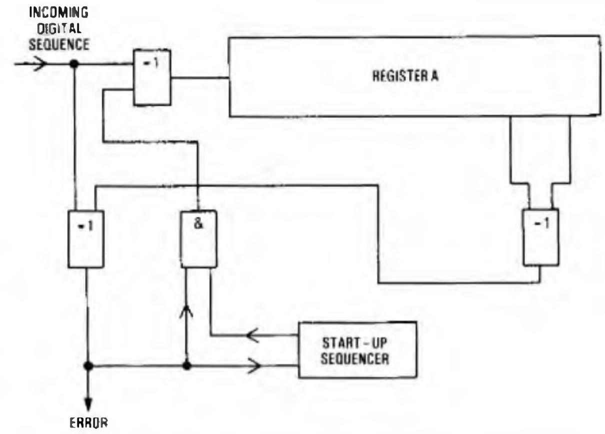


FIG. 6—Alternative design of improved error-detector

A PRACTICAL CIRCUIT

A block diagram of a $2^n - 1$ bit pseudo-random error detector, which incorporates all the features previously described, is shown in Fig. 5. The self-start mechanism searches for an 11 bit period of the incoming sequence which is free from errors, before it frees register B to start the true error detection sequence.

When first powered, the initial-start circuit gives a clear pulse to the divide-by-11 counter, via gate G6; another pulse triggers the bistable formed by gates G7 and G8 to clear register B. The divide-by-11 counter then starts counting. Provided no error pulses have arrived when it has counted to 11, the counter's output pulse triggers the bistable to remove the clear from register B to start the true error detection sequence. If error pulses arrive during the counting sequence, the counter is reset and starts counting again. The inversion process is carried out in gates G4 and G5.

It is possible that particular error sequences occuring during the start-up period could cause a false start situation but, as this occurence would have a low probability, this situation has been ignored in this instance. To reduce the probability even further, the counter length can be altered to provide a no-error count of 32 or more bits.

Fig. 6 shows an alternative design of error detector based upon the same principle as the one shown in Fig. 5. However, in this case, the element that would have been shifted into register A has been corrected beforehand; thus, in this alternative design, register B and an EXCLUSIVE-OR gate is deleted from the circuitry which is shown in Fig. 5.

CONCLUSION

The improved error detector described in this article can be incorporated in test equipment for use in detecting errors produced in any digital equipment or systems. At present, it is being incorporated into a 64 kbit generator and error detector which is being developed for use on data and PCM systems in the British Post Office (BPO) telephone network. The detector is capable of detecting errors when the rate is greater or less than 1-in-n, (where n is the length of the shift register) and when multiple errors are present in a burst. Moreover, it does not require any form of synchronization. The only requirement is for a single n bit period when no errors are present; if this were not the case, then the error rate would be so high that the system under test would be in a complete failure mode.

ACKNOWLEDGEMENTS

The author acknowledges the previous work done on this subject by various people, including that of R. J. Westcott and others in the BPO Research Department, and extends his thanks to P. N. Ridout and D. W. Parkinson of the BPO Research Department for their advice in the preparation of this article.

Britain Shows The Flag in South America

D. V. CLARK†

The beautiful city of Rio de Janeiro in Brazil was the host for INTELCOM 80, the major international telecommunications exposition which was held between 19–23 May of this year. Following its notable successes of last year at the TELECOM 79 exposition in Geneva and COMMUNICASIA 79 in Singapore, the British Post Office (BPO) was a major participant at INTELCOM 80, both in the large and attractive display of products and services it mounted, and in the range of papers its members presented during the conference, which ran in parallel with the exhibition.

The exposition, with the theme of *Creating the future today*, was organized by Horizon House, the publishers of *Telecommunications Magazine*, as part of a series of international expositions in the developing world. INTELCOM 80 was held at a purpose-designed conference and exhibition centre built in open countryside about 20 miles outside Rio de Janeiro. One exhibitor likened the centre to the National Exhibition Centre without Birmingham. Like most exhibitions INTELCOM 80 did not open without its full share of problems beforehand. The British exhibitors, together with most of the foreign participants, encountered excessive difficulties in getting their equipment released by the Brazilian customs authorities. Despite many promises and much pressure, many exhibitors had still not even received their exhibits 3 days before the exhibition was due to open. As the dead-line approached, the British exhibitors genuinely wondered whether they would be able to display any equipment at all. It was literally at the eleventh hour before packing cases arrived on-site, and many hours of hard work before the British stands were made ready and resplendent.

The opening ceremony of the 5-day exposition, which was performed by Senõr Haroldo Correa de Mattos, the Brazilian Communications Minister, was attended by representatives from many other Latin American countries. A special guest at this ceremony was Mr. J. S. Whyte, Deputy Managing Director of the BPO. Other special guests, including national representatives from France, Italy and Germany, reflected the major European presence at this event. After the opening ceremony, Senõr Haroldo Correa de Mattos, special guests and other dignatories toured the exhibition, for which there was considerable television and press coverage. The conference sessions and the exhibition were well attended by senior people from many South American countries, as well as by delegations from further afield, including representatives from Kenya, Malaya and Malta. Over 140 companies or organizations participated as exhibitors.

Thirteen British companies participated in the exhibition under the auspices of a British Overseas Trade Board joint venture, sponsored by the Electrical Engineering Association. The British pavilion displayed a wide range of products and services, which included data and message switching equipment, modems, electronic teleprinters, data printers, visual display units, facsimile equipment, line transmission and submarine communications systems, test equipment, precision waveguides, line plant and a variety of customer telephone equipment that had been designed and developed in Britain.

The centrepiece of the British pavilion was the joint stand of the BPO and British Telecommunications Systems Limited (BTS), showing Britain's competence in advanced telecommunications, and examples of the latest products and services. Many warm comments were received from visitors about the design of the stand, and the presentation and technical quality of the equipment on display. A novel feature of the stand was the several large Union Jack panels mounted above it. These were eye-catching and immediately visible from all parts of the exhibition hall. Moreover, within 24 hours another exhibitor had copied this idea.

As at previous international exhibitions, the principal exhibit on the joint BPO/BTS stand was System X, the integrated, modular family of stored-program control (SPC) digitally-switched electronic exchanges that will carry the British telecommunications network into the next century. BTS, the company established by the BPO and its partners in System X—GEC, Plessey and STC—to promote exports of the system, undertook the presentation and demonstration of System X with a team led by Mr. John Sharpley, the Managing Director. A working digital con-

† Marketing Executive, Telecommunications Headquarters

Mr. J. S. Whyte, Deputy Managing Director, BPO, addresses the convention

The joint BPO/BTS stand

Visitors at the joint BPO/BTS stand

The British Ambassador, Mr. G. E. Hall, and his wife see Prestel on the BPO stand

centrator, which acted as a small local exchange, was installed on the stand to demonstrate the facilities offered by System X. This, together with an animated lamp display, slow-scan television and the new range of Ambassador telephones having access to recorded commentaries in 6 languages, proved to be a valuable aid in describing and demonstrating the capabilities of System X.

Another major attraction on the stand was Prestel, the world's first public viewdata service, which was connected on-line from London and which was being shown for the first time in South America. Picture Prestel, the latest enhancement from the BPO Research Department, caused quite a sensation and added a tremendous impact to the appeal of Prestel. Also featured on the Prestel display were large-screen domestic terminals, small colour business terminals, a hard copy printer and a small alphanumeric keyboard. At the conference Mr. Mike Ford, Deputy Director of Prestel, used new projection equipment which allowed Prestel to be projected onto a large screen—on-line from London—to give effortless viewing during the several presentations that were given to enthusiastic audiences. As at previous exhibitions, Prestel was a prime attraction for visitors; and on the occasion of its unveiling in South America, Brazilian press and television gave it a very warm reception, which was reflected in the excellent coverage it received both during and after the exhibition. Prestel was featured on *TV Globo*, the largest commercial television station in Brazil, at the lunch time and evening news spots, and the Brazilian Government sponsored television company, *TV Education*, filmed samples of Prestel pages. Prestel's international debut in South America was clearly a major attraction at the exhibition.

In addition to System X and Prestel, the BPO display included a wide range of fully working exhibits of the latest customer products and services. Central to this display was the Monarch 120 PABX, an all electronic, digital SPC PABX, which is now going into quantity production. As well as being used for demonstrating its facilities, the Monarch 120 system acted as a switching system for the other customer products on display. These products included Herald, the new press-button office telephone system that uses micro-electronics to make available many new facilities previously only possible with a large PABX, the new Ambassador range of telephones, a high quality loudspeaking telephone, radiopaging, and ABC Alarms—an alarm communication system, which the BPO has developed and which is now in service in East Anglia.

Besides showing new products and systems, the BPO/BTS stand also highlighted Teleconsult, the overseas consultancy service which is backed by the large resources and expertise of the BPO. The Teleconsult team, led by Mr. Frank Thomas, Director of Overseas Liaison and Consultancy, received many enquiries over a wide range of telecommunications topics. The many new contacts made during the exhibition confirm that Teleconsult has a positive role to play in the development of telecommunications in South America.

During the conference the 11 papers presented by British representatives were well attended and generated lively discussion. In addition, British representatives chaired 2 conference sessions, and made a special half-day presentation of UK products and services.

The last day of the exhibition was British National day, the highlight of the week for the UK contingent. This was the day Her Majesty's Ambassador to Brazil, Mr. G. E. Hall, and the Consul General in Rio, Mr. S. Egerton, and their wives, supported by other members of the consular staff, visited the British stands. Their tour of the stands, escorted by a colourful Scottish piper and enhanced by the distribution of 5000 English roses, highlighted Britain's presence and provided a considerable attraction for visitors. The event attracted television camera crews, and good shots were filmed of the British stands and shown on the Brazilian TV news. A highly successful evening reception, attended by 150 guests, firmly and enjoyably rounded off the day.

In reviewing INTELCOM 80, mention must be made of the invaluable help provided by the local British Consulate and the untiring efforts of its staff on behalf of the British exhibitors. It is difficult to judge the impact of an exhibition such as INTELCOM 80. Perhaps it is too early to make an assessment because of the time span involved in telecommunications activities; but all the British stand staff were very encouraged by the large number of telecommunications people who attended the exhibition. Certainly, the level of interest in British products and expertise, and the many useful contacts made during the exhibition made INTELCOM 80 another successful venture; the task now is to bring these to fruition for the benefit of Britain and British Industry.

The 60 MHz Frequency-Division Multiplex Network

R. W. BALLINGER†

UDC 621.394.44.029.62: 621.315.212

This article gives a brief review of the provision of the 60 MHz frequency-division network, which is now approaching completion.

INTRODUCTION

The increasing traffic requirements of the late-1960s indicated a need to extend the circuit capacity of coaxial cables on which major telecommunication undertakings were operating 12 MHz frequency-division multiplex (FDM) systems on trunk routes. Feasibility studies initiated by the CCITT* indicated that, by taking advantage of the by then well established semiconductor technology, standard 2·6/9·5 mm coaxial cable could be exploited up to 60 MHz (nominal), with repeaters spaced at 1·5 km intervals.

The economics of the 60 MHz FDM system restricted its use in the UK to the traditional high growth rate routes, such as London–Birmingham and Birmingham–Manchester. In the arrangement adopted by the British Post Office (BPO), High Wycombe became a nodal point between London and Birmingham with a spur to Reading. The addition of the Birmingham–Manchester route enables direct 60 MHz links, each with a capacity of 10 800 telephone circuits, to be set up from London to Reading, Birmingham and Manchester, and from Birmingham to Reading and Manchester. (See Fig. 1.)

A field trial of the equipment and cable was carried out at Marlborough in 1972, and a pilot scheme to demonstrate the installation of cable and repeater housings took place at Marlow.

In October 1973, a special issue of this *Journal* was devoted entirely to the 60 MHz FDM system[1], the articles being written in the light of experience of the field trials. The value of those trials can be gauged from the fact that, with few exceptions, the provision of the 60 MHz network, now approaching completion, has proceeded using the designs and practices set out by authors of those articles, and the results predicted have been achieved.

This article reviews some aspects of that provisioning story.

BPO SCHEME FOR 60 MHz WORKING

The BPO scheme for using the 60 MHz systems was to couple the dramatically increased capacity of each coaxial pair (from 2 700 telephone circuits on one 12 MHz system to 10 800 circuits on one 60 MHz system) with an 18-pair coaxial cable, which was routed so as to afford a high degree of security. This was achieved by doubling the depth at which cable is normally laid to 1·2 m, or by affording equivalent protection. Most of the route followed roads, but some cross-country routeing was used. Serious consideration was given to laying the London–Birmingham cable alongside the London (Paddington)–Birmingham (Snow Hill) railway line, but this was not adopted because of access problems.

Two pairs of the cable were equipped with a system normally in standby mode, but able, by means of automatic switching equipment, to take over the traffic from either, or both, directions of a failed system. Inner layer pairs were selected for the standby system because service statistics indicated that the predominant mechanical damage to cables rarely extended to the inner pairs. Secure accommodation and dedicated power plants have been provided for 60 MHz equipment installations.

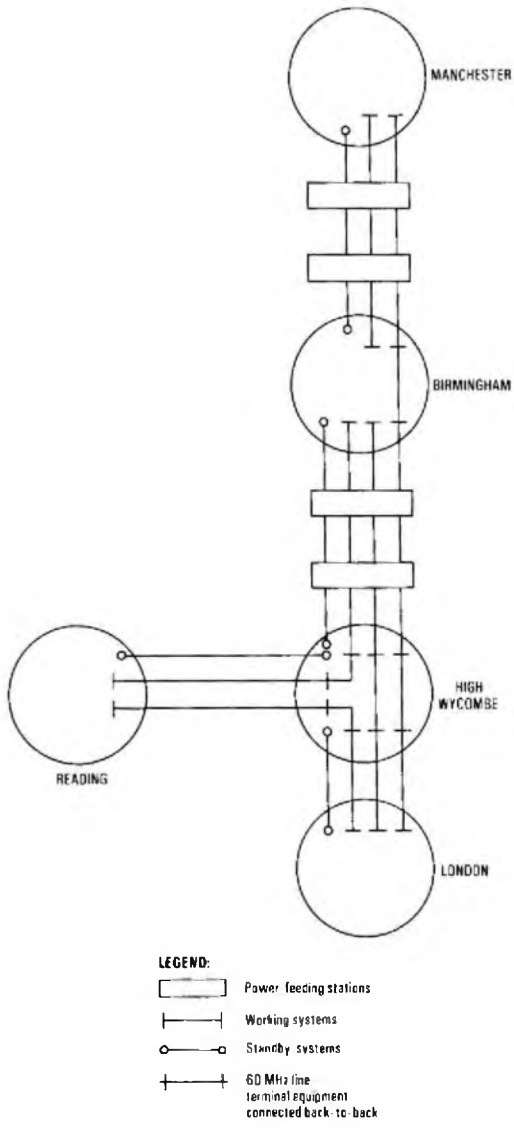


FIG. 1—The 60 MHz FDM network

† Transmission Department, Telecommunications Headquarters

* CCITT—International Telegraph and Telephone Consultative Committee

DUCTWORK AND HOUSINGS

The total route length of the 60 MHz network is 375 km. It has 259 manholes constructed to house repeater cases and 747 jointing manholes. The plan was to pull in cable lengths of 500 m, thereby reducing the amount of jointing to the minimum practicable, with only two intermediate joints in each 1·5 km repeater section. In practice, this could be achieved on only 102 out of 266 sections. The main reason was that a route that avoided other plant and provided safe working positions for manholes could seldom be straight, and lengths shorter than 500 m had to be used.

Precast manholes were originally proposed for some locations, but this concept was abandoned when the idea of routeing alongside the London to Birmingham railway line was dropped in favour of conventional road routeing. Precast manholes require a large excavation, which was seldom convenient. No situation was encountered that required the silo buried repeater station[2]; this was designed for use in particularly wet locations.

Manholes were constructed *in situ*, using excavation, shuttering and reinforced concrete. The dimensions of manholes used to house repeater cases were 4 m × 2 m × 2·3 m high and those used as normal in-line jointing chambers were 3 m × 1·2 m and 2·15 m high. Both types are more than twice the size of manholes used on previous coaxial routes.

Throughout the route, two duct bores were laid so that a second cable could be installed subsequently if required. Occasionally, where an overground interruption cable could not be used, a complete maintenance bore was provided between adjacent manholes. The work of laying the duct proceeded at a satisfactory rate. It involved excavating a deeper and wider trench than normal and was not without incident; 8 km of the route through rock sub-soil took 13 months to complete, some five times longer than on better soils and, on a moorland section, an unmapped mineshaft was encountered.

A standard polyvinylchloride (PVC) water main pipe was used for most of the duct length, except where normal practice called for steel pipes or the route utilized previously provided ducts. The PVC duct had an internal diameter of 105 mm and that of the epoxy red-oxide lined steel was 102 mm. The two types could be directly connected.

The PVC pipe, with its socket end terminating in each manhole and compound-smeared joints, was used not only to provide a low-friction surface through which to pull the cables, but also to provide a dry route[3]. This has not been entirely successful and, on many sections, the plant, including repeater cases, will spend much of its life in a wet situation.

For the approaches to the major centres, use was made of existing cable tunnels.

Accurately marked steel measuring ropes were used to obtain measurements between duct faces on completion of duct sections. This allowed cable drum lengths to be manufactured within fine limits, thereby reducing wastage of expensive cable. Occasionally, the pre-cabling check with brush and mandrel revealed duct deformities; some were investigated using a claw-action duct measuring device, which presented the information on a chart. A television probe was also used.

CABLE

The 18-pair 2·6/9·5 mm coaxial cable was made up within a lead sheath, to which was added a coating of bitumen and an over-sheath of blue polyethyelene. These provided additional protection against corrosion and the polyethyelene also gave a low friction surface. A maximum overall diameter of 78 mm was specified for this cable, the largest used by the BPO, and this ensured that a "sniffer" device could be passed through a duct containing the cable to detect pressurization leaks.

On the Marlborough field trial, the cable was pulled into the repeater station up cable risers and along cable racking to the equipment area, where it was intended to terminate it on a cable terminating rack. The state of the cable at the end of its journey, however, indicated the need to reduce the size of the cable within repeater stations and to make other arrangements for terminating it. Furthermore, a cable terminating rack did not suit the requirements of the power-feeding safety arrangements because it would have provided an accessible break point. Consequently, it was arranged that each cable approaching a 60 MHz repeater station was reduced from one 18-pair to three 6-pair cables at a convenient point in the tunnel or in a manhole adjacent to the repeater station cable chamber.

The 6-pair cables were then routed to a point adjacent to the equipment racks, where each cable was jointed to six 1-pair lead-covered coaxial cables. Finally, above the position of the equipment rack served by the individual pairs, an air-seal joint was used to convert the lead cable to a flexible coaxial cable with a plug on the flying end for connexion to the equipment. (See Fig. 2.)

Positions of breakdown joints varied, although a standard pattern was achieved for main (power-feeding) stations. A high standard of workmanship was achieved on the cables, which will stand as a tribute to the plumber jointers art. Fig. 3 shows the arrangements at High Wycombe, where cables enter from London, Birmingham and Reading as 6-pair cables, and 1-pair cables, rise to leave at high level to the equipment area.

Although many experienced cabling personnel had some doubts, most cable lengths were pulled in without the winch rope tension approaching the limit. Liquid paraffin applied to the cable sheath proved an effective lubricant[4]. On one section, where a length was pulled through an intermediate manhole in a slight downhill direction, the cable became impelled by its weight and entered the intermediate manhole faster than when it left; this had a disastrous effect on that cable length and it had to be replaced.

Plastic clamps were used to anchor the cable to the bearers in manholes. However, where cable creepage occurred, it was necessary subsequently to brace the bearers to prevent them pivoting about the unistrut junction with the wall members.

As intended, the comprehensive range of tests applied to the cables[5] ensured their suitability for digital working at

FIG. 2—Air-seal joints converting lead-sheathed cable to plug-ended flexible cable

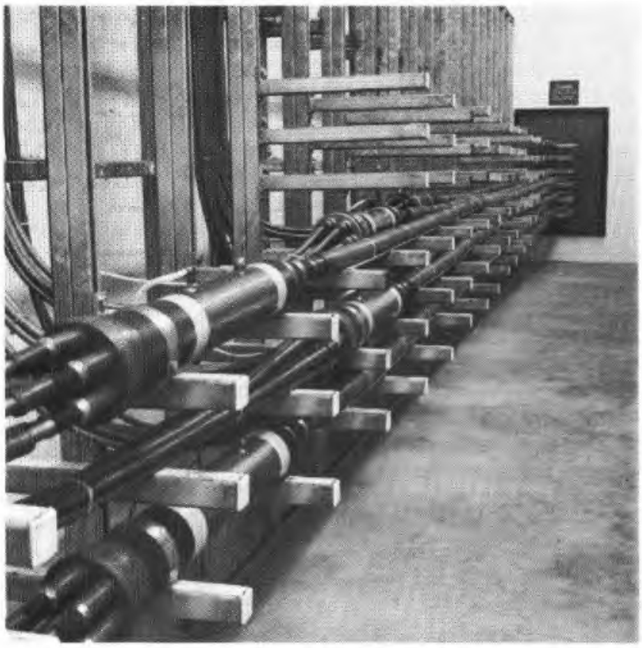


FIG. 3—The 60 MHz cabling arrangement in High Wycombe cable chamber

500 Mbit/s or higher-rate working. Indeed, the quality of the cable is far above that needed for 60 MHz FDM operation.

REPEATER CASES

The repeater cases[2] are made of cast aluminium, with nylon coating on all external surfaces. Overall dimensions of the main section are $1{\cdot}35$ m $\times$ $0{\cdot}58$ m $\times$ $0{\cdot}465$ m deep. The volume available for equipment is some three times greater than that provided by cases used previously.

Various problems were encountered with minor air leaks from early production cases. Checks instituted on pipework unions, air-box lead-through and air-switch fitting minimized defects in later stages. In some corrosive areas, investigation is continuing to determine the effect on stainless steel nuts, bolts and washers used for lid closure and also on plated fittings.

The cable and repeater cases between two 60 MHz repeater stations form a continuous pneumatic circuit. Air pressure is maintained in the cable and repeater cases by cable pressurizing equipment connected at each end of a section between two 60 MHz repeater stations. The compressors and dessicators used are of standard design, but are not connected direct to the cable. Instead, they are used to supply dry air to an air receiver, or reservoir, where it is stored at high pressure before passing to the cable via regulator valves at 162 kPa (9 lb/in^2).†

Each repeater case contains two pressure-sensing devices (contactors). One is set to operate at 150 kPa and controls the operation of an oscillator, which is also housed in the repeater case and which has a unique frequency for identifying the repeater. When pressure falls to 150 kPa, the sensing device disconnects the output of the oscillator from a control pair in the cable. The loss of the unique frequency enables cable-pressure monitoring equipment at the repeater stations to identify the repeater case concerned. This information is presented as a print-out, giving date, time and location. Subsequent failures at adjacent repeater cases are also recorded. This information, coupled with that concerning the pneumatic resistance of the cable, enables close location of the actual leak position to be made in cable sections up to 66 km long.

The second contactor is set to operate at 145 kPa and is connected to a simple cable alarm arrangement, which enables the position of a contactor to be located with a Murray bridge. This provides an alternative to the oscillator arrangement.

† The international system of units, published by the British Standards Institution, uses the *Pascal* as the unit of pressure. However, the *Bar* is still in common use: 1 millibar = 100 Pa.

THE MULTIPLEX EQUIPMENT

Each 60 MHz line system can carry up to 10 800 circuits, and the line spectrum is nominally 4–60 MHz, into which twelve 900 circuit hypergroups are assembled. (See Fig. 4.) The equipment to perform the first stage of assembly (that is, hypergroup modulation[6]) was already available as part of the translating equipment for 12 MHz FDM systems; this was therefore provided in the familiar 62-type construction.

The 60 MHz hypergroup translating equipment[6], which assembles the twelve hypergroups, the master frequency generator[7], the line system[8] and the protection switching equipment[9], have all been provided in a proprietary form of construction, colloquially called *conclave*. The name derives from the enclosed nature of the form of construction, being composed principally of screened units within hermetically-sealed boxes, which plug into base plates mounted vertically on a rack. The racks are half the depth of 62-type racks, but adapted easily for installation with BPO standard superstructure and practices. Fig. 5 shows the installation at High Wycombe and Fig. 6 shows a unit removed from a conclave rack.

Field commissioning tests on 60 MHz multiplex equipment followed a similar pattern to those adopted for lower-order systems, but the increased bandwidth and additional features required more time on site to set up and test. For example, on each 60 MHz frequency translating equipment, there are twenty-four 4 MHz bands and two 60 MHz bands to be set up and checked for insertion-gain/frequency response and spurious frequencies. Use was made of XY plotters and spectrum analysers to facilitate commissioning.

The extremely high accuracy specified for the 60 MHz

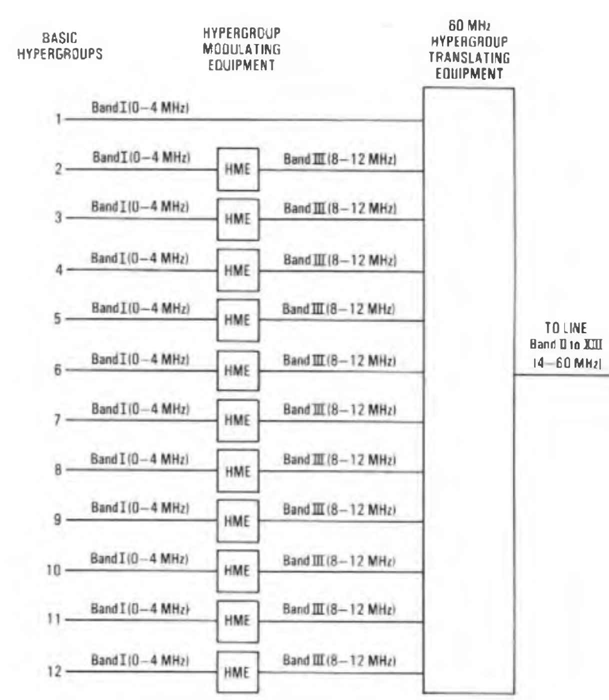


FIG. 4—Assembly of 12 basic hypergroups

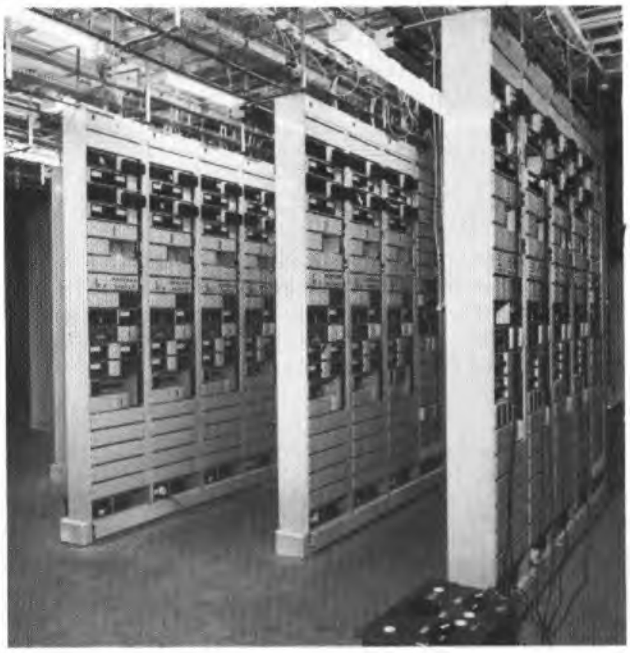


FIG. 5—The conclave equipment installation at High Wycombe

(Equipment for the 60 MHz network was manufactured and installed by PYE/TMC in association with Philips Telecommunicatie Industrie BV)

FIG. 6—A unit removed from a conclave rack

master frequency generating equipment, together with the fact that its supplies include frequencies of 124 kHz, 440 kHz and 2·2 MHz, made it suitable for use at certain submarine terminal stations, and four equipments were ordered for this purpose.

A practical difficulty arose because the specified final drift rate of 2 parts in 10^9 per month was required to be reached within 2 years. This meant that final acceptance of 60 MHz master frequency generators might be prolonged by as much as a year beyond normal contract periods. The issue was complicated by earlier field trial results, which showed that four out of six master oscillator units had exhibited an unsatisfactory drift-rate performance. To enable satisfactory equipment to be identified and accepted within a normal contract period, a guidance curve for drift rate performance

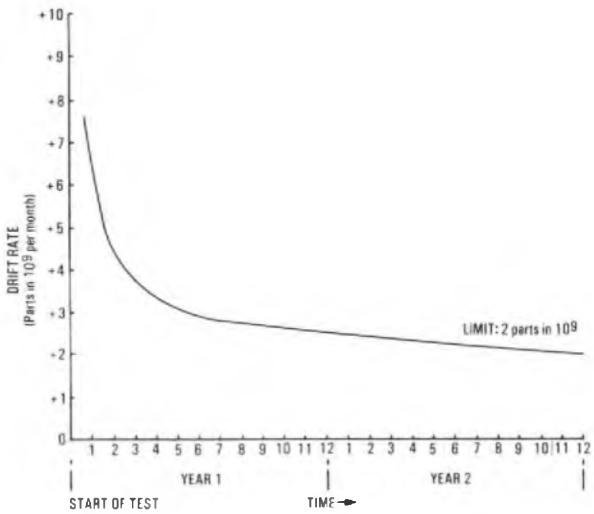


FIG. 7—Guidance curve for long-term frequency stability of frequency generating equipment

was constructed (see Fig. 7). This was coupled with an agreement that equipment performing within the limits of the curve in the early periods would be acceptable. Close quality control of the crystal encapsulation process during production of master oscillators eliminated the earlier problem and, in the event, all were accepted without the need for prolonged testing.

THE LINE EQUIPMENT

Notable features of the 60 MHz line system are the power-feeding and system-regulation arrangements. Both are controlled by signals between 5 kHz and 17 kHz, which bypass the dependent amplifiers by using the power-feeding path. Once adjusted to the requirements of a section, these features have proved satisfactory.

The power-feeding system adopted by the BPO for the 60 MHz system uses constant-current generators at each end of a section; these deliver a current of 110 mA and develop a maximum voltage of 500–0–500 V. Each dependent amplifier requires 21 V, which limits the number of amplifier points in a section to 43 (a length of 66 km). This necessitated the provision of two power-feed stations between Birmingham and Manchester and also between Birmingham and High Wycombe. Thus, both routes have three main sections, which must be treated as separate transmission entities before lining up the overall route.

Following installation and in-station tests on line equipment racks at each end of a section, the coaxial pairs forming each system were looped together at a midway amplifier point. The dependent amplifiers were installed by working outwards from each station up to the temporarily looped position. Amplifiers were preset in the factory for specific positions, using data obtained from cable test results.

Tests were made to each amplifier point to check the loss of the preceding cable section and the gain of the amplifier inserted. The midway loops enabled the amplifiers provided for both directions to be checked, using power fed and controlled from one end. The loops also allowed amplifiers to remain powered and warmed up, so that they gave steady gain from the time of installation onwards. This became more necessary as the number of amplifiers preceding those being tested increased.

Regulated amplifiers were normally provided at every fifth position and initial settings for the appropriate cable temperature were made by manual adjustment of the controlling 2·9 MHz pilot.

The amplifier installation phase of the work was occasionally hampered by the presence of gas, and excessive water caused delays at some locations. Pre-installation checks of amplifiers ensured few delays were attributable to equipment defects.

A typical result for the spread of the amplitude/frequency response on a section of the Birmingham–Manchester route was 1·25 dB, which reduced with bump equalization to 0·37 dB. A 14-section twin-cosine equalizer was used for the final equalization of a 60 MHz system, which might comprise several sections. Associated test equipment items were a cosine coefficient computer and a 14 spot-frequency oscillator, the outputs of which lay outside or between traffic signals of the 4–60 MHz band. Initial measurements were made at each frequency and this information was conveyed to the computer. The output from the computer enabled these levels to be manually readjusted by controls on each equalizer section. The work described took only a few hours per system.

The final spreads on the amplitude/frequency responses obtained between Birmingham and Manchester for the three systems installed were 0·31 dB, 0·05 dB and 0·09 dB.

CONCLUSIONS

At the design stage of the 60 MHz line system, much emphasis was placed on reliability. This has now been supplemented at the works stage by providing cable and equipment of a very high quality, which have met performance limits with adequate margins. It is confidently expected that, in service, the 60 MHz FDM network will prove to be the most reliable means of routeing trunk circuits so far adopted by the BPO.

The editorial of the October 1973 of this *Journal* posed the question "will this be the last in the line of succession for high-capacity analogue system?" The digital demand of the System X modernization strategy surely makes the answer "yes".

However, if the BPO decides to introduce future high rate digital line systems requiring a high-quality coaxial cable, the BPO has one ready on its primary route and a duct bore for a second.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the colleagues who have previously contributed detailed articles on the 60 MHz line system and also the conscientious and enthusiastic participation of other BPO staff and those in Industry in the provision of the 60 MHz network.

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Post Office Press Notice

BOUQUET FOR DR. FLOWERS

The British Post Office (BPO) has launched a new silver medal award for BPO engineers. The award, which is to be known as the *Martlesham medal*, will be presented annually to present or past employees of the BPO who have made a significant contribution to telecommunications science and engineering.

In June of this year Dr. Tommy Flowers, the acknowledged father of electronic switching and the man who invented Britain's, and possibly the world's, first computer, became the first recipient of this new award when Sir William Barlow, Chairman of the BPO, presented it to him at a special ceremony and private lunch held in London's Savoy Hotel. During the course of the lunch, which was attended by many distinguished guests from the field of electrical engineering, including Mr. Peter Benton, Managing Director: Telecommunications, and Mr. J. S. Whyte, Deputy Managing Director: Technology, Sir William paid tribute to Dr. Flowers' skill and vision, for which, he believed, Industry and the BPO owed him a lasting debt.

Dr. Flowers was born in London and joined the BPO in 1926. Even before the Second World War began he appreciated the intrinsic advantages of electronics technology—high operating speed and freedom from wear; by 1939 he was well experienced in electronic circuit design.

During the war he worked at the BPO's research establishment at Dollis Hill; for a time he was employed on work for Government Communications Headquarters at Bletchley Park, where his initial work in connexion with the German Enigma coding machine earned him an MBE. As it was necessary to decipher quickly the messages produced by Enigma, he developed the equipment which speeded up the code-breaking process. But his greatest achievement proved to be his invention of the *Colossus* machine, so called because of its size, since it helped to break the code of the German *Geheimschreiber* (the secret writer) which was thought to be impregnable. Hitler used this machine to send messages to his generals at the front. Colossus gave the allied forces access to a stream of secret information about German war plans and it was working 2 years before its nearest equivalent, of American design, was at work.

After the war he used his specialized knowledge to pioneer work on electronic and computerized telecommunications. Although his early ideas and concepts make up much of today's telecommunications technology, when he conceived them the transistor had not been invented and the most advanced technologies of the day were the cold cathode tube and the thermionic valve.

In 1964 he left the BPO to work on electronic switching for STC; after leaving STC he did consultancy work and wrote a book on electronic communications. Although he is now retired, he still uses his inventive powers by making custom-built aids for disabled people at his local hospital.

Facsimile Communications

UDC 621.397.12; 621.39

The information given in this article is reproduced from the 'Post Office Research Review 1979', a publication issued by the British Post Office Research Department. The article comments on the internationally-agreed standards for the provision of facsimile communication systems and describes the operation of a system that could form part of an advanced office communication system.

STANDARDS

Facsimile systems for the remote copying of documents were first developed over 100 years ago, but only recently has there been a real commitment to establish internationally-agreed standards. In this field, an important part of the work of the British Post Office (BPO) Research Department is the support of standards by independent research into the merits of different transmission systems and protocols. At present, there are three internationally-agreed methods of transmitting facsimile signals over public telephone networks (see Table 1).

Standardization and improvements in scanning and printing technologies have both stimulated the growth and development of document facsimile.

The 6 min analogue Group 1 standard, which has been in existence for some years, but which was not well supported, has now been largely superseded by the 3 min analogue Group 2 standard.

The Group 2 standard was ratified by the International Telegraph and Telephone Consultative Committee (CCITT) in 1976 and, subsequently, the number of facsimile machines which conform to this standard has increased rapidly (see Fig.1). The facsimile service recently introduced by the BPO also uses this standard.

In recent years there has been much interest in the development of digital source encoding, which will allow shorter transmission times to be achieved. The Group 3 standard was drafted in 1977 and, although there are few facsimile machines which conform to it at present, it is expected that the number will rise substantially in the near future.

The CCITT is at present considering optional extensions to the Group 3 data-reduction method. Whereas the basic coding method reduces the amount of data required to transmit a document by removing horizontal redundancy, extended coding methods achieve further data reduction by also removing vertical redundancy. For example, the extended coding methods will allow typical A4 documents, scanned at 3·85 and 7·7 lines/mm, to be transmitted in about 45 s and 75 s instead of 1 min and 2 min respectively when the basic coding method is used. Therefore, when high copy quality is required, extended coding methods are particularly useful for documents scanned at high resolution. The BPO Research Department, in co-operation with several other PTT administrations and manufacturers, has assessed the performance of these proposed codes in terms of their efficiencies, sensitivities to transmission errors and ease of implementation. It is hoped that an international agreement concerning the extension can be ratified this year.

Because of the increasing availability of public data networks (both packet and circuit switched), an initial definition of Group 4 facsimile has been drafted to cover the application of facsimile on such networks. With the low error performance achieved by these networks further developments in data compression techniques are being considered.

The four methods of facsimile transmission are viable only when the co-operating terminals are able to converse with each

TABLE 1
Summary of Existing Facsimile Standards Applicable to Public Telephone Networks

Group 1 (Analogue)	
Transmission time	6 min/A4 page
Vertical resolution	3·85 scan lines/mm (equivalent horizontal resolution)
Transmission method	Frequency modulation (1700 ± 400 Hz)
Group 2 (Analogue)	
Transmission time	3 min/A4 page
Vertical resolution	As Group 1
Transmission method	Vestigial-sideband amplitude modulation (2100 Hz carrier). Bandwidth reduction achieved by encoding of baseband signal
Group 3 (Digital)	
Transmission time	About 1 min/A4 page (typical typescript document)
Resolution	3·85 lines/mm and 1728 picture elements/215 mm scan line. High resolution option (7·7 lines/mm). Signal quantized to black and white only
Data reduction	Statistical method based on Huffman code
Transmission method	Digital modulation at 4·8 kbit/s

FIG. 1—Typical Group 2 facsimile machines

other to establish, maintain and terminate the communication process; this requires the precise definition of terminal-to terminal procedures or protocols. A CCITT Recommendation now exists covering the protocols for Groups 1, 2 and 3, which also allows the possibility of interworking between facsimile terminals supporting more than one method of transmission.

Developments in microprocessors are now enabling more comprehensive, structured protocols to be developed. These will provide Group 4 facsimile with a degree of network independence that is not available at present. Present international collaboration is aimed at developing a common protocol which will be suitable for future facsimile and text-based communication services. It is intended that this protocol will provide the basis of future integrated office communication systems, but the protocol will not be restricted to any particular network.

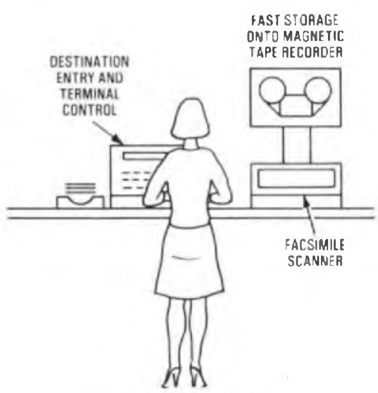
FONOFAX SF: AN AUTOMATIC DOCUMENT TRANSMISSION SYSTEM

The Fonofax SF system represents an initial step towards the use of facsimile as part of a more advanced office communication system.

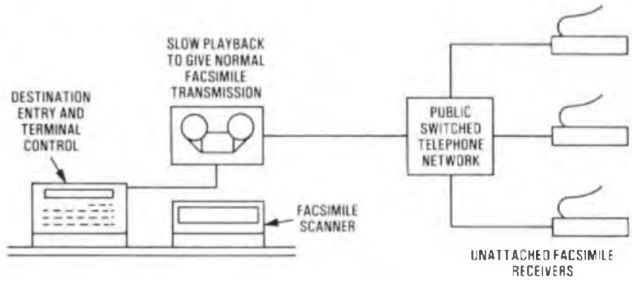
FIG. 2—Document being loaded into the Fonofax SF system

Documents can be loaded via a fast scanner onto magnetic tape during office hours (see Fig. 2) by untrained personnel. The documents can then be transmitted automatically during preselected periods without the need for an operator to be present. This facility could allow transmission during low-tariff periods. Documents are received on conventional Group 2 apparatus at a speed which enables an A4 sheet to be reproduced in 3 min. A block diagram of the Fonofax SF system operation is shown in Fig. 3.

Each item is transmitted to every telephone number for which it is intended. If the transmission is not successful, the



(*a*) Input phase



(*b*) Transmission phase

FIG. 3—Fonofax SF system operation

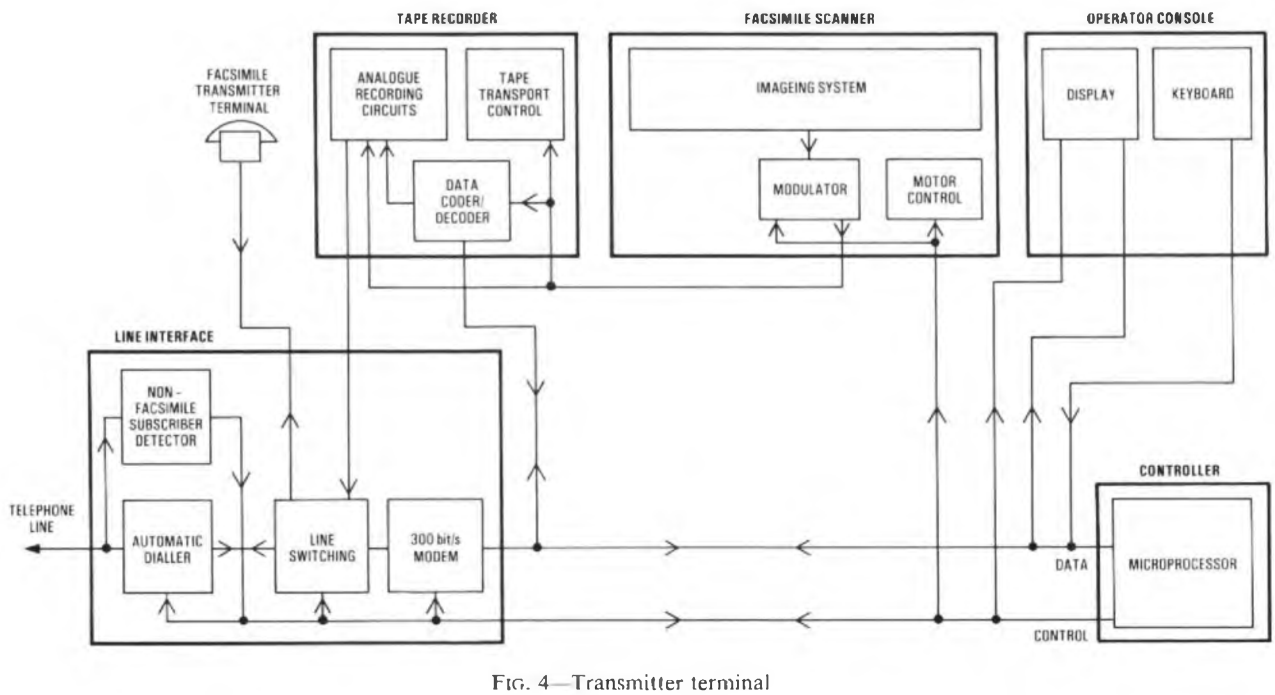


FIG. 4—Transmitter terminal

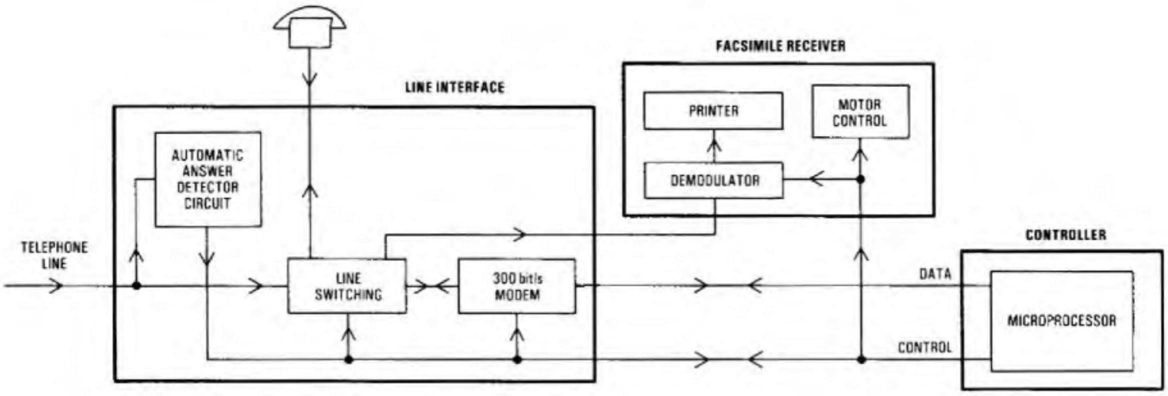


FIG. 5—Receiver terminal

document is logged for a repeat attempt after the transmission of any others on the tape. These repeat attempts can continue until the end of a transmission period.

If the apparatus is connected to a non-facsimile subscriber, ringing tone will continue beyond two bursts; this fact is logged and the call is immediately terminated. No further call will be attempted to this number.

On answering, the receiver sends back its national telephone number as a means of identity. This number is checked at the transmitter before the document is transmitted. Block diagrams of the transmitter and receiver terminals are given in Figs. 4 and 5 respectively.

The system can be interrogated at any time, except during the transmission phase, to determine which items have not been sent, and the reasons for failure. These documents can then be retrieved from the tape and sent manually.

The system is microprocessor-controlled and human factor considerations have been incorporated to facilitate ease of use.

This project has provided the impetus for several significant developments, notably, a suitable analogue tape unit based on a commercially available 'Elcaset', capable of storing about 100 documents, and a fast scanner (11 s for an A4 document) using a solid-state array.

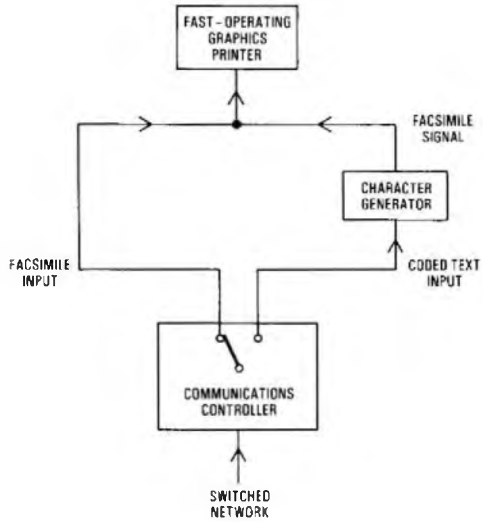


FIG. 6—Combined facsimile and text printer

FACSIMILE AS PART OF A FUTURE INTEGRATED OFFICE SYSTEM

Facsimile printers and some text printers are now tending to use the same technology. With a suitable interface, a single printer terminal could therefore be used to receive both facsimile and coded-text information. Either could be used, depending on the form of the source material; they could even be intermixed within the same page. An interface unit has been built at the BPO Research Centre to demonstrate this concept of enabling both text and graphical information to be received on a fast printer (300 characters/s).

This concept could be extended to include other office communication services when the necessary standards and protocols are developed.

An Unusual Method of Supporting Underground Cables during Construction of a New Road

J. C. DUNCAN, A.M.I.B.E.†

INTRODUCTION

Owlsmoor, a community consisting of several hundred houses, a few shops and a school, is set amidst coniferous trees and gorseland just north of Sandhurst in Berkshire. The telephone service in the parish is provided by the telephone exchange at Crowthorne, a small village next to Owlsmoor.

In late 1979, the controlling housing authority granted developers planning permission to build a housing estate of some 550 houses of Elizabethan character within the Owlsmoor district. The project involved the construction of a dual carriageway and an intersection complex to link it to the existing Owlsmoor road, which carried the main ductways from the Crowthorne exchange into Owlsmoor.

To facilitate the construction of the intersection, the developers requested that the underground plant impeding the progress of works in this section be diverted. However, this was not practicable since, owing to industrial action by computer operating personnel at national level which affected requisitioning procedures, the cables needed to effect the diversion were not available and there was a critical shortage of some engineering stores. In order not to hamper the progress of the road and housing development programme, unorthodox methods were of necessity adopted by both the Planning and the External Works Construction staff.

PLANNING

Owlsmoor had been regularly monitored for speculative building projects for several years, and contingency plans had been in hand to cater for any sudden telephone demand in a given area.

Two pressurized unpigmented polyethylene-sheathed cables of 300 and 1600 pair capacity, were routed individually in 92 mm diameter glazed-earthenware ducts on opposite sides of the road, to serve Owlsmoor from the Crowthorne exchange. Information received from the developers indicated that it was necessary for the British Post Office (BPO) not only to divert the ducts but to lower them beneath the finished levels of the new dual carriageway to allow construction of the intersection to be completed. Fig. 1 shows the end elevation of the Owlsmoor road with the proposed new road cutting transversely through it.

A physical survey of the route disclosed that insufficient cable slack existed in the adjacent jointing chambers to effect the slewing and lowering manoeuvres. Moreover, it proved impossible to obtain cable of any length to piece-in a short section. Consideration was then given to converting the underground cables to an aerial route by using the existing cables.

Pilot holes were excavated at intervals along the length of the affected track to ascertain essential data regarding its depth and the geographical location of other undertakers' plant within the vicinity. Theoretical consideration given to the suspension design concluded that a catenary wire support system in combination with a linear wire that was tensioned and stretched parallel to the track would provide optimum results. By this means each cable would have its own support system erected on opposite sides of the new road. Fig. 2 shows the system it was proposed to adopt.

The duct line was to be exposed along its length before the linear wire was strung and tensioned. Linking wires would then be fixed to both the linear and the catenary wires; the ducts would be broken open and the cable secured to the linear wire.

However, the choice of poles and staying methods proved not to be straightforward, as the peculiar nature of the soil needed to be taken into account. Owlsmoor is situated within the area known as the *Bagshot Beds*, a collective name for a series of sands dating from the Eoscene age, which occupy extensive tracts of land throughout Berkshire, Surrey and Hampshire. These sands have a scant covering of topsoil, beneath which there exists a patchy layer of flint pebbles resting on sand, which in places is 60 m deep. Some evidence indicates that the upper layer of sand was deposited in salt water and, although generally devoid of fossils, some indistinct casts of shells can be occasionally found. The sand, which shows signs of tidal currents, was probably once the estuary of a great river that had gradually subsided. Because of the unreliable mechanical stability of sand and its inherent low holding strength, special consideration had to be given to determining the dimensions of poles and stay-anchoring devices. Originally the developers had requested a span length

† Reading Telephone Area

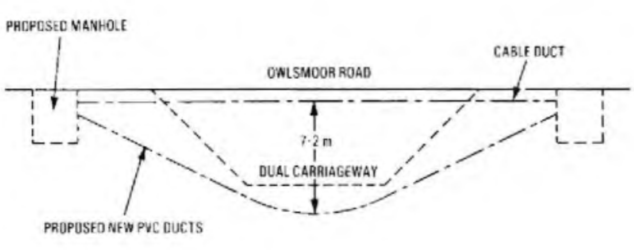


FIG. 1—Elevation of Owlsmoor road with proposed new road cutting through it

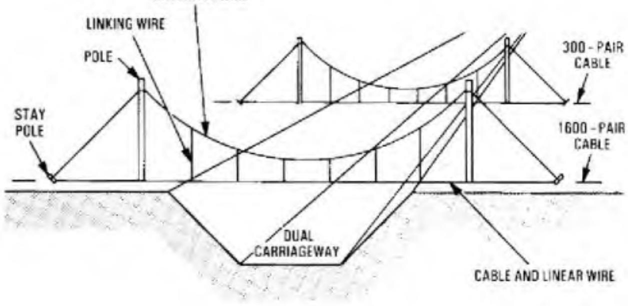


FIG. 2—Elevation of catenary support across dual carriageway

of 90 m, so that vehicles could operate without hindrance. However, with some temporary rearrangement of the public access slip-roads a compromise was reached, and an acceptable 65 m span with a cable-sag clearance over the site of 4 m, well above the minimum permissible vehicle clearance height, agreed. This allowed a margin of clearance that was just enough for ram-operated excavating buckets to swing their jibs carefully into the air to drop excavated spoil into the tipper lorries.

Within the constraints applied by the stores shortage, the poles selected were of medium size and 9 m in length. The evaluation and analysis of yield strength data given for the conventional size stay anchor in sand was disappointing: the ultimate holding strength was 16·7 kN, whereas in comparison it was 52·3 kN in crumbly damp chalk. Under these circumstances it was decided not to install stay anchors but to employ medium-size pole stumps 5 m in length, as these were of sufficient length to terminate 2 stay wires on each stump. Calculations that were made indicated that a pole stump of 5 m would provide a holding strength of 35 kN and that it would provide a safety margin against the distinct possibility of mechanical impact from heavily laden earth-moving vehicles. Moreover, a large pole stump rising out of a flat terrain would be more visible to vehicle operators.

The aerial construction was designed to last for 9 months; its short lifetime was not due to its physical structure, but to the durability of the cable; in particular, the life expectation of the unpigmented polyethylene sheath under these conditions. There are 2 reasons for this: degradation of the natural polyethylene sheath by light-exposure, and elongation of the cables by tensile creepage, a phenomena which is assisted by thermal softening of the sheath by warm sunlight absorption. Visible light, a natural source of power, is only about half as energetic as sunlight; nevertheless, it contains sufficient strength to break the carbon-to-carbon bonds within the unpigmented sheath. In consequence, this promotes sheath discoloration, which leads to embrittlement and to eventual fracturing.

The incessant bombardment of the cables by this relatively low-energy source of radiation throughout the anticipated exposure time was not considered to be sufficiently deleterious to have an appreciable effect on cable performance. It was envisaged that tensile creepage would be of an immeasurable amount if the cable was securely lashed to the tensioned linear wire.

INSTALLATION

It had been agreed with the developers at the planning stage that their groundworks contractor would uncover the duct tracks on each side of the road and that a side trench would be cut parallel with the ducts to allow working access for the BPO construction party.

After exposing the track, the pole erection unit, using the conventional motor-driven lorry-mounted auger, drilled pole-holes approximately 3·3 m deep next to the ducts. When the line-poles had been erected, the pole stumps selected for back-staying were inserted at a depth of 2·2 m, angled against the projected pull-on-pole, and positioned to give a base/height ratio of equal length. Because of wind and ice-loading tensioning requirements, the choice of suspension wire was limited to the few types that had been obtained from various sources. For the 1600-pair cable, which has a diameter of 66 mm, a coil of 7/4 mm (7/8 SWG) wire was earmarked for the linear wire; the catenary wire, and that needed for staying requirements, was adequately covered with 7/2 mm (7/14 SWG) wire, which was available in sufficient quantity.

On a day when the thermometer was reading 1°C the linear wire was tensioned to 16·1 kN between the poles by using a dynamometer, a chain puller and a block and tackle. Counteracting the tension of the linear wire was a back-stay provided in line with the linear wire and terminated on the

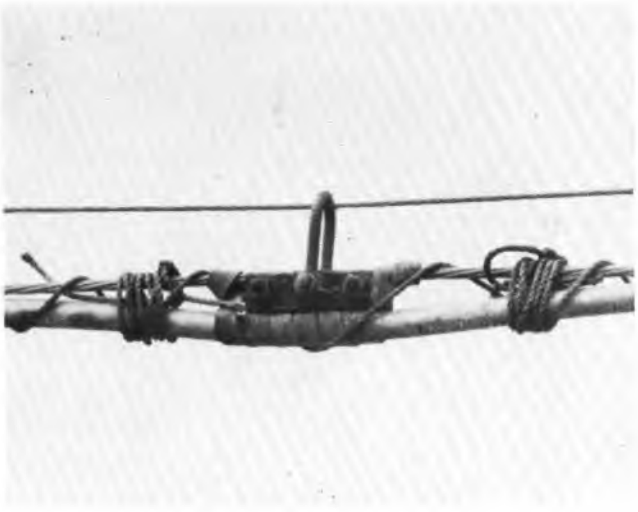


FIG. 3—Type of clamp adopted

pole stumps provided for staying. After the linear wire had been tensioned, the catenary wire was suspended from the top of the line poles in parabolic fashion. Vertical connecting wires were then terminated by using clamps to join both wires. Fig. 3 shows the method adopted and the type of clamps used. Stay wires were provided at the top of the poles to counteract the catenary wire strain, and these wires were terminated on the same pole stumps as those holding the linear stays. Because of the close proximity of a national grid electricity pylon route of 400 kV, insulators were fitted to the stay wires. When the wire and staying structure had been completed, the glazed earthenware ducts were carefully broken open; this task was made more difficult by ice-clusters, which had formed after torrential rain had fallen some days previously and which had bound the cables to the ducts.

Draw rope was used to lash the cables to the linear wire, and cable restrainers fitted to the cables in the jointing chambers at each end of the interrupted section. This was to prevent cable joints from being dragged into the duct mouth in the event of excessive movement caused by the natural sag of the suspended cables.

The cables, now completely suspended but still at ground level, were left for several days, but inspected periodically to ascertain whether any movement had taken place in the structures. Confident that the designed system would withstand the flexural and dynamic stresses calculated from known failure data, the contractors then proceeded to demolish the road. After the road construction had been completed, 2 further poles were erected close to the kerb line as an extra safety precaution.

CONCLUSION

Undoubtedly projects of the type described in this article are challenging in comparison to conventional methods. Cost comparison studies indicated economical savings could result by adopting similar modes of construction based on the applied techniques. As a public relations exercise it rated very highly. The Local Authorities, in conjunction with the architects and major construction companies directly involved, appreciated the unstinting assistance given by the staff of the Reading Telephone Area in overcoming a difficult situation at a critical period in the building programme.

ACKNOWLEDGEMENTS

The author would like to acknowledge the valued assistance given to him in the preparation of this article by colleagues in the Reading Area External Planning Division, External Construction staff and members of the Drawing Office.

Profiles of Senior Staff

SENIOR DIRECTOR: PROCUREMENT

S. SWALLOW, M.A., F.INST.P.S.

Sam Swallow is a relative newcomer to the British Post Office, which he joined as Senior Director: Procurement in 1977. Apart from a period of wartime service with the Royal Engineers, his whole career has been spent in purchasing, contracting and supply.

His first job after leaving Cambridge University was as a temporary Assistant Principal with the Mining Supplies Directorate of the Board of Trade. In 1946 he joined Britain's first nationalized industry, the National Coal Board, just before vesting day, as a Planning Assistant (Supply). Over the next 13 years he played a significant part in the development of the Board's procurement activities: he held planning and executive posts; latterly he was Chief Contracts Officer. In 1959 he moved to the Central Electricity Generating Board as Assistant Chief Officer: initially he dealt with maintenance and engineering stores, subsequently with major construction contracts.

In 1965, he was approached by Associated Electrical Industries (AEI), and became their corporate Controller of Purchasing: he held a similar post with GEC after their take-over of AEI. From 1968 until 1977 he was Director of Supplies for the Greater London Council, a job in which the principle element, rather surprisingly in the public service, was to head a large trading organization supplying numerous local and other public authorities on a competitive and profit-making basis.

He is actively involved in the field of procurement education. He chaired the Institute of Purchasing and Supply's education committee for many years, and currently holds a visiting lecturer's appointment at Henley administrative staff college.

DIRECTOR: PRESTEL

R. HOOPER, B.A.

Richard Hooper, who was born in Wool, Dorset, began his career as a television and radio producer with the BBC, after he had obtained a first class honours degree in modern languages at Worcester College, Oxford.

In 1967 he was awarded a Harkness Fellowship in the United States to study educational and communications technology. Returning to the BBC in 1969, he spent two years as the senior producer in the Faculty of Educational Studies at the Open University, before he left to become Director of the Government-sponsored National Development Programme in Computer Assisted Learning, a post which he held for 5 years.

From 1978 until he was appointed Director of Prestel in the British Post Office earlier this year, he was Managing Director of Mills and Allen Communications, one of the first major information providers on Prestel. While working for Mills and Allen, he pioneered the concept of the umbrella information provider, which has become a major feature of Prestel's growth.

As Director of Prestel, he looks forward to developing the service rapidly to cater for millions of customers in the 1980s and to retaining Britain's world lead in viewdata technology.

He is married, has three children and lives in north London.

DIRECTOR: MANAGEMENT SERVICES AND SCIENCES

S. LILLIE C.ENG., M.I.E.E.

Stewart Lillie joined the British Post Office (BPO) in 1940 as a Youth-in-Training in Newcastle Telephone Area. After service in the Royal Navy as a Radar Mechanic, he returned to maintenance work in rural north Northumberland; in 1950 he moved to the Engineering Department in London as an Assistant Executive Engineer, followed by 8 years in Bedford Telephone Area on maintenance and installation work. As a Senior Executive Engineer, he returned to the Engineering Department just as the productivity drive of the 1960s was getting under way, and for 5 years played a leading part in the numerous innovations introduced on installation work, including the one-man installer and the appointment plan. This was followed by 3 years as an Assistant Staff Engineer helping to secure productivity improvements in the field in what later became the Productivity Improvement Division. He then transferred to pay and grading work, first in Telecommunications Headquarters as an Assistant Secretary, then later as a Director in Central Headquarters. In September 1979 he returned to Telecommunications as Director of the newly formed Management Services and Sciences Department.

DIRECTOR: PAY AND GRADING

D. W. PORTER

Derek Porter sat the Open Competition for Assistant Engineer in 1948, and, while waiting for an appointment, joined South West Regional Headquarters as a Draughtsman-in-Training. His appointment to the Bristol Telephone Area came nearly a year later; however, he had to leave shortly afterwards to complete 2 years National Service with the REME.

From his return to the British Post Office in 1951 until he left the South West region in 1968, he was engaged on external planning and works in Area and Regional offices. His promotion to Executive Engineer, via the Limited Competition, came in 1958, and to Area Engineer in 1966.

Success in the special selection for Deputy General Manager (DGM) meant a move to the London Telecommunications Region (LTR) where, as a DGM in both North and City Areas, he widened his experience of all aspects of customer service.

In January 1973 he moved again, this time to the Midland Telecommunications Region, where as Planning Controller (External) he was able to make use of his early experience. Later, as Service Controller, he was able to draw upon the knowledge he had gained in LTR.

In 1976 he returned to London to work for the first time in Telecommunications Headquarters (THQ). As Head of the Grading Division, he was well able to appreciate the field repercussions of agreements made with unions. He also made his first acquaintance with proposals for grade restructuring; however, just as Government pay policy was starting to provide an opportunity to engage in discussions on this with the unions, he left to become a Deputy Director in LTR. After 18 months in these familiar surroundings he returned to THQ as Director: Pay and Grading.

DIRECTOR: TELECOMMUNICATIONS FINANCE

D. J. TUDGE

David Tudge is one of a number of postal business refugees who are now making their careers in telecommunications. He joined the British Post Office (BPO) Midland Region Headquarters at Birmingham in 1959 as an Assistant Postal Controller and travelled the Region extensively in his early years. A very interesting two-year period in Nigeria was followed by work study at Postal Headquarters.

Promotion to Principal brought a move from postal work to broadcasting policy when he became secretary to the Television Advisory Committee. Keen to stay in the BPO after it became a Corporation, he moved to the BPO Appointments Centre when it was established; later he was appointed to the office of the Chairman, Lord Hall.

It was not until after Mr. Tudge had completed a sabbatical year as a Sloan Fellow at the London Business School that he entered finance work. Service in Central Finance Department (CFD), Postal Finance Department and then Telecommunications Finance followed. Promotion to Deputy Director in Telecommunications Systems Strategy Department introduced new worlds (although still with an economic or financial slant). He had a short sojourn again in CFD before he returned to the Business as Director: Telecommunications Finance.

His main interest when he is not working is education, especially that of his two young daughters. He is a governor of Mayfield School, Putney, and is active on Inner London Education Authority parent consultative committees.

DIRECTOR: INTERNATIONAL NETWORK

C. J. MAURER, C.G.I.A., B.SC.(ENG.), F.I.E.E.

John Maurer joined the British Post Office (BPO) in 1939 as a Youth-in-Training at Exeter. After serving in the Royal Air Force from 1942–45 on radar duties, he returned to the Exeter Area to Unit Automatic Exchange maintenance duties. In 1949 he joined the signalling group of the Telephone Branch as an Assistant Engineer and was later promoted to Executive Engineer. During this period he was engaged on the development of London Faraday International exchange. In 1958 he graduated from London University with a degree in electrical engineering, and in 1961 he received an Insignia Award from the City and Guilds of London Institute (CGLI). As a Senior Executive Engineer he joined the newly formed Electronic Exchange Development Branch (TPE) to work on the high-speed time-division multiplex electronic-exchange development.

On promotion to Assistant Staff Engineer in 1969, he represented the BPO at the signalling and switching study group meetings of CCITT and CEPT. During this period he was responsible for the technical evaluation of the International Switching Centre at Stag Lane. After he was promoted to Staff Engineer in 1972, his Branch responsibilities covered electronic exchange developments and all types of customer apparatus. In 1975 he joined the External Telecommunications Executive as a Deputy Director. After a short period in the Exchange Switching Division, he returned to the newly formed International Executive as the Director: International Network.

During his career he has taken an active interest in the CGLI, and for a number of years was the Chief Examiner for advanced telephony. For the past 7 years he has been the Chairman of the Moderating Committee for all of the CGLI Telephony and Telegraphy examination papers.

Book Review

Teletext and Viewdata. S. A. Money, T.ENG.(C.E.I.), M.B.C.S., T.I.T.E. Newnes Technical Press. 151 pp. 100 ills. £5·50.

The title of the book is Teletext and Viewdata, but about 100 pages are devoted to broadcast teletext compared with 23 pages for viewdata. The section on teletext is well written and explains its principles clearly and in considerable detail. The operation of digital components, such as character generators and memories, is explained from first principles for the benefit of engineers and technicians who are mainly familiar with analogue television techniques, and the section is notable for the large number of simple, clear diagrams it contains. The operation of teletext decoders, and the page and row structure of broadcast teletext are fully explained. Topics of practical value, such as eye-height displays, are included; these make this section extremely useful.

The section on viewdata is also well written and adequately covers the major elements of the system, but the depth of treatment given to broadcast teletext is lacking. For example, there is nothing on data entry for viewdata, although there is a chapter devoted to teletext production at the studio. Considering both the technical and commercial importance of viewdata information providers and their editing facilities, this omission is disappointing.

A chapter is devoted to describing the proprietry decoders produced by TI, Mullard and by GI, GEC and Labgear; it also contains information of prime interest to maintenance technicians. Although useful and comprehensive at present, this material must be vulnerable to the rapid changes (both technical and commercial) that are occurring in this area.

Only 3 pages are devoted to possible future developments, and this is meagre considering the plethora of comment and speculation that has been made on the future of electronic publishing and data dissemination. Related developments overseas, such as *Antiope* and *Telidon*, receive even shorter shrift, and are dismissed in 10 lines, despite the fact that the choice of international standards for viewdata and teletext is proving as contentious as that for a colour television standard.

However, the book is well printed and bound, and reasonably priced. The technician or engineer requiring a detailed introduction to broadcast teletext will find it most useful, but the telecommunications strategist concerned with the future of electronic publishing may find it a little limited.

K. E. CLARKE

Institution of Post Office Electrical Engineers

General Secretary: Mr. R. E. Farr. THQ/NE/NS4.1.3, Room S04, River Plate House, Finsbury Circus, London EC2M 7LY; Tel. 01-432 1954
(Membership and other local enquiries should be directed to the appropriate Local-Centre Secretary as listed below)

ESSAY COMPETITION 1980–81

Details of the special Essay Competition being organized for 1980–81 to celebrate the forthcoming 75th Anniversary of the foundation of IPOEE are given on the opposite page.

THE FEDERATION OF TELECOMMUNICATIONS ENGINEERS OF THE EUROPEAN COMMUNITY (FITCE)

The FITCE Executive Committee has agreed in principle to the concept that certain IPOEE members without the required academic or professional qualification should be allowed to join FITCE during a limited period (see report in January 1980 issue of the *Journal*), but has expressed concern at the number thus eligible in relation to the membership from other countries. Council has agreed to the continuation of negotiations on the basis of a possible overall limit on the number of IPOEE members permitted to become members of FITCE.

CONSTITUTION OF THE COUNCIL 1980–81

Council for 1980–81 is constituted as follows:

Mr. D. Wray, Chairman.
Mr. A. B. Wherry, Vice-Chairman.
Mr. D. V. Davey, Vice-Chairman.
Mr. A. V. Knight, Honorary Treasurer.
Mr. A. G. Leighton, representing Group 1 (members in the Headquarters Departments and the London Regions holding posts in bands 1–8 of the Senior Salary Structure).

Mr. W. N. Lang, representing Group 2 (members in the provincial Regions holding posts in bands 1–8 of the Senior Salary Structure).

Mr. R. D. Edwards, representing Group 3 (members in the Headquarters Departments (London) holding posts in bands 9–10 of the Senior Salary Structure).

Mr. F. V. Spicer, representing Group 4 (members in the London Regions holding posts in bands 9–10 of the Senior Salary Structure).

Mr. B. H. House, representing Group 5 (members in the provincial Regions and in Headquarters Departments (provinces) holding posts in bands 9–10 of the Senior Salary Structure).

Mr. J. M. Avis, representing Group 6 (members in the Headquarters Departments (London) listed in Rule 5(a), with the exception of those in Group 14).

Mr. J. W. Turnbull, representing Group 7 (members in the London Regions listed in Rule 5(a), with the exception of those in Group 14).

Mr. L. W. F. Vranch, representing Group 8 (members in the provincial Regions and in Headquarters Departments (provinces) listed in Rule 5(a), with the exception of those in Group 15).

Mr. M. E. Barnes, representing Group 9 (members in the Headquarters Departments (London) listed in Rule 5(b), with the exception of those in Group 14).

Mr. J. D. Overall, representing Group 10 (members in the London Regions listed in Rule 5(b), with the exception of those in Group 14).

Mr. D. F. Ashmore, representing Group 11 (members in the provincial Regions and in Headquarters Departments (provinces) listed in Rule 5(b), with the exception of those in Group 15).

Mr. D. V. Gasson, representing Group 12 (Inspectors in the London Regions).

Mr. N. R. Paul, representing Group 13 (Inspectors in the provincial Regions).

Mr. M. E. Webb, representing Group 14 (Draughtsmen, Illustrators and above, but below the Senior Salary Structure, in Headquarters Departments (London) and London Regions).

Mr. C. G. Suett, representing Group 15 (Draughtsmen, Illustrators and above, but below the Senior Salary Structure, in provincial Regions and Headquarters Departments (provinces)).

Mr. P. M. Annett, representing Group 16 (all affiliated members).

Representation for Groups 5 and 15 was contested. The unsuccessful candidates, in descending order of votes cast were:—

Group 5 Messrs. G. T. Davies, G. Brice and P. W. Hodnett.
Group 15 Messrs. D. R. Norman, F. Brown and J. C. Clarke (the last two named polled equal votes).

MEETING OF LOCAL-CENTRE SECRETARIES

Local-Centre Secretaries meet annually under the chairmanship of the General Secretary, together with other members of the Secretariat and the Managing Editor of the *Journal*, to discuss organizational and other problems. This year's meeting was held at POTTC, Stone on 23–24 June. A wide range of topics was discussed and the Chairman thanked all Local-Centre Secretaries on behalf of Council for their continuing work for the Institution.

R. E. FARR
Secretary

IPOEE CENTRAL LIBRARY

The books listed below have been added to the IPOEE library since the publication of the 1974 Library Catalogue. 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.

5300 *Health and Safety*. K. P. Davis (1979)

This textbook, which is intended for TEC and BEC courses, should be of interest to anyone with control of staff or premises.

5301 *High Performance Loudspeakers*. M. Colloms (1980)

The many theoretical and commercial developments in high quality loudspeaker design during the last decade have gone largely unrecorded. This book provides a comprehensive and up-to-date account of these design techniques, covering both driver units and complete systems.

5302 *Computers and Commonsense*. R. Hunt and J. Shelley (1979)

This book is a down-to-earth guide to computers and computer systems, progressing from simple principles to advanced modern systems.

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

75TH ANNIVERSARY ESSAY COMPETITION

A UNIQUE ANNIVERSARY **SILVER MEDAL** WILL BE AWARDED FOR THE BEST ESSAY ON A THEME CONCERNED WITH THE FUTURE ROLE OF BRITISH TELECOM.

IN ADDITION, PRIZES WILL BE AWARDED IN EACH OF THE FOLLOWING SECTIONS:

1 A total of **£100** for up to five essays submitted by Members of the Institution in all Post Office/British Telecom grades of the rank of Inspector and above but below the Senior Salary Structure.

2 A total of **£100** for up to five essays submitted by Post Office/British Telecom engineering staff below the rank of Inspector.

Each Award will be accompanied by a Certificate of Award. In addition, up to five Certificates of Merit may be awarded in each Section.

YOUR SUBJECT: ANY TOPIC RELATING TO ENGINEERING ACTIVITIES IN THE POST OFFICE/BRITISH TELECOM, OR TELECOMMUNICATIONS ENGINEERING GENERALLY, IS ACCEPTABLE, BUT ONLY ESSAYS ON THE GIVEN THEME WILL BE ELIGIBLE FOR THE MEDAL

Technical accuracy is essential but a high standard of technical content is unnecessary. Creative thought, clearness of expression, the correct use of words and presentation are all taken into account. Typewritten or manuscript entries are acceptable.

YOUR ESSAY SHOULD CONTAIN BETWEEN 2000 AND 5000 WORDS
BE ON A4 SIZE PAPER
INCLUDE A CERTIFICATE IN THESE TERMS:

I certify that this Essay is my own unaided work as regards composition and drawing.

Name (in block capitals) ....

Official Address ....

Signature .... Rank .... IPOEE Centre ....

Date ....

SEND YOUR ENTRY TO The Secretary (EC), IPOEE, THQ/TP5.3.1,
16th Floor, St Alphage House, Fore Street,
LONDON EC2Y 5XA

CLOSING DATE 15TH JANUARY 1981

The Council of the Institution reserves the right not to award prizes or certificates if the essays submitted are considered not to be of a sufficiently high standard.

5303 *Microelectronics: Digital and Analog Circuits and Systems.* J. Millman (USA, 1979)

A comprehensive digest of integrated circuit devices and their uses in digital and analogue circuits.

5304 *Microwaves.* A. J. Baden Fuller (1979)

An introduction to microwave theory and techniques, this book provides a theoretical development of electromagnetic propagation of guided waves and material properties, together with a descriptive treatment of microwave components and measurements.

5305 *Electronics for Technicians.* R. Hamilton (1979)

This book has been written as an accompaniment to courses leading to a TEC certificate which requires a knowledge of electronics at levels II and III. It concentrates on the principles of light-current electrical engineering with particular relevance to communications and industry.

5306 *Elements of Computer Science.* G. Emery (1979)

This book aims to provide a fuller introduction to computing and computer technology than is found in most publications on the subject. It places emphasis on the mathematical concepts fundamental to computer science and has a comprehensive treatment of the principles of analogue and hybrid computation.

5307 *Scientists and Inventors.* A. Feldman and P. Ford (1979)

This is an illustrated guide to the theories and practical achievements of 150 of the World's great inventors and scientists. Set out in chronological order, the book gives an account of human progress told through the lives of outstanding men and women gifted with imagination and ingenuity.

5308 *Teletext and Viewdata.* S. A. Money (1979)

This is one of the first books on an increasingly important field of telecommunications. The concepts and technicalities of information presentation are explained in basic terms with numerous diagrams and illustrations. The book is mainly devoted to *Ceefax*, *Oracle* and *Prestel*, though world-wide developments are also examined.

5309 *Energy.* Scientific American (USA, 1979)

A compilation of energy articles from recent issues of *Scientific American*, this book summarizes the current energy supply technologies and examines the options for the future.

2247A *Radio and Electronic Laboratory Handbook.* M. G. Scroggie and G. G. Johnstone (1979)

This latest edition (the ninth) of this standard work is written using SI units and has been revised to include recent developments and new techniques.

R. Cross
Librarian

Local-Centre Secretaries

The following is a list of Local Centre Secretaries, to whom enquiries about the Institution should be addressed. It would be helpful if members would notify any change in their own address to the appropriate secretary.

Centre	*Local Secretary*	*Address and Telephone Number*	
Birmingham	Mr. D. F. Ashmore	MTR HQ, PLX1.1, 95 Newhall Street, Birmingham B3 1EA	021-262 5407
Eastern (Bletchley)	Mr. D. R. Norman	General Manager's Office, ED9.3, Telephone House, 25-27 St. John's Street, Bedford MK42 0BA	(0234) 55860
Eastern (Colchester)	Mr. P. M. Cholerton	ETR HQ, PLG2.1.4, St. Peter's House, St. Peter's Street, Colchester CO1 1ET	(0206) 89547
East Midlands	Mr. D. W. Sharman	General Manager's Office, ES3.3, 200 Charles Street, Leicester LE1 1BB	(0533) 534409
London	Mr. M. S. Armitage	NC/CP, Fleet Building, 40 Shoe Lane, London EC4A 3DD	01-829 4467
	Mr. L. J. Hobson	THQ/ME/BS4.4.3, Tenter House, 45 Moorfields, London EC2Y 9TH	01-432 1385
Martlesham	Mr. A. F. Hare	BPO Research Centre, ResD/R2.1.2, Martlesham Heath, Ipswich IP5 7RE	(0473) 642139
North Eastern	Mr. D. Spencer	NETR HQ, S131, 36 Park Row, Leeds LS1 1EA	(0532) 467529
Northern	Mr. L. G. P. Farmer	General Manager's Office, C128, Swan House, Pilgrim Street, Newcastle-upon-Tyne NE1 1BA	(0632) 27212
Northern Ireland	Mr. W. H. Tolerton	General Manager's Office, EC1, Dial House, 3 Upper Queen Street, Belfast BT1 6LS	(0232) 24777
North Western (Manchester and Liverpool)	Mr. W. Edwards	NWTB HQ, F2.3, Telecommunications House, 91 London Road, Manchester M60 1HQ	061-863 7178
North Western (Preston)	Mr. R. L. Osborn	General Manager's Office, PS, Telephone House, Fenton Street, Lancaster LA1 1BA	(0524) 88400
Scotland East	Mr. S. Walker	STB HQ, P312, Canning House, 19 Canning Street, Edinburgh EH3 8TH	031-222 2361
Scotland West	Mr. G. A. Dobbie	General Manager's Office, EX14, Marland House, 40 George Street, Glasgow G1 1BA	041-220 2697
South Eastern	Mr. J. M. Smith	SETR HQ, PL/LT1.2, 52 Churchill Square, Brighton BN1 2ER	(0273) 201318
South Western	Mr. D. P. Cosh	SWTB HQ, Sv2.3.1, Mercury House, Bond Street, Bristol, BS1 3TD	(0272) 295578
Stone/Stoke	Mr. J. Coulson	Post Office Technical Training College, TP7.2.9B, Stone, Staffs ST15 0NQ	(0785) 813631 Extn. 511
Wales and the Marches	Mr. D. A. Randles	WMTB HQ, PW3.1.2.2, 25 Pendwyallt Road, Coryton, Cardiff CF4 7YR	(0222) 391370

CENTRE PROGRAMMES 1980–81

Eastern (Colchester)

Meetings will be held at the University of Essex, commencing at 14.00 hours, unless otherwise stated.
15 October: *Optical Fibre Development and Use* by D. Brace.
12 November: *Advances in Food Processing Instrumentation* by R. Connell. To be held at the Assembly Rooms, Norwich, commencing at 14.00 hours.
10 December: *LSI Design in the Post Office* by A. E. Jacketts.
14 January: *Telecommunication Systems in Hong Kong and East Africa* by K. McKenna and S. A. Downing.
11 February: *Energy and Nuclear Power* by B. Skelcher.
11 March: *Interim Planning Rules for 2 Mbit/s PCM* by J. Warburton.
22 April: *Future Trends in Customers' Apparatus* by G. J. Pocock. This is a joint meeting with the Bletchley Centre and will be held at 14.00 hours in the Guildhall, Cambridge.

Martlesham Heath

Meetings will be held in the John Bray Lecture Theatre at the Post Office Research Centre, commencing at 16.00 hours.
8 October: *Telecomms in Australia* by S. A. Deighton.
23 October: *High-Speed IC Techniques* by P. J. T. Mellor and R. J. Hawkins.
5 November: *Advances in Microwave Radio—Better Communications Through a Fickle Medium* by W. K. Ritchie.
18 November: *The Cambridge Digital Ring* by D. J. Wheeler.
10 December: *Telephones for Consumers* by R. R. Walker.
15 January: *Radiophone Research and Development* by J. Garrett and J. R. Ball.
3 February: *Surface Acoustic Wave Devices* by E. G. S. Paige.
25 February: *Distributed Processing for the Control of Telephone Exchanges* by M. H. Barton and L. A. Jackson.
19 March: *External Plant* by G. E. Haines.
7 April: *Sub-Micron Lithography* by M. E. Jones.
13 May: *The Terminal Scene* by C. E. Rowlands.

Stone/Stoke

Meetings will be held at the Staffordshire Fire Brigade Headquarters, Bethesda Street, Hanley, Stoke-on-Trent, or at the Post Office Technical Training College (POTTC), Stone, at 13.45 hours with the exception of the Joint meetings on 15 December and 26 February which will commence at 19.00 hours.
13 October (Stoke): *Telecom Pricing Policy* by G. J. Jones.
10 November (POTTC): *Microprocessors (16 bit)—Their Impact on Control and Automation* by G. Trickey.
8 December (Stoke): *Nuclear Energy* by L. Curtis.
15 December (POTTC): *Recent Developments in Land Mobile Radio* by W. Gosling. (Joint meeting with the Institution of Electrical Engineers and the Institution of Electronic and Radio Engineers.)
12 January (POTTC): *Digital Transmission of Video-Audio Signals Over Optical-Fibre Systems* by N. H. C. Gilchrist.
9 February (Stoke): *Intelpost (Electronic Mail)* by K. Spence.
26 February (POTTC): *Prestel* by K. E. Clarke. (Joint meeting with the Institution of Electrical Engineers and the Institution of Electronic and Radio Engineers.)
9 March: *Euronet* by J. Gordon.

The Associate Section National Committee Report

The Seventh Technical Quiz Final and National Awards

The seventh national technical quiz final took place on 25 April at the Institution of Electrical Engineers' Theatre, London. This year's finalists were Oxford and Inverness.

Mr. Norman Clarke, once again acting as Master of Ceremonies, introduced Mr. R. E. G. Back, Senior Director of Network Executive, and the many invited guests and their wives. The quiz final was a close fought battle (the teams had equal scores at the half-time interval) and Inverness emerged as the eventual winners.

The final question was put to the quiz master of long standing, Mr. Frank Thomas, who was asked to identify an object held by the ex-quiz organizer, Mr. Kevin Marden. The mystery object was correctly identified by Mr. Thomas as a brandy warmer, for which he received 3 points, and the brandy warmer in recognition of his years of service to the National Committee.

Mr. Back then presented the Bray Trophy to Mr. R. G. Swanson, captain of the victorious and splendidly dressed Inverness team.

The Chairman of the National Committee, Mr. Brian Headley, then asked Mrs. Back to present the Cotswold Trophy to the Centre, Region or Board deemed to have contributed most to further the aims of the Associate Section during the year. This year's winner was Midland Region.

This was followed by the National Committee's Projects Organizer, Mr. Joe Anning, introducing this year's winning project for the E. W. Fudge Trophy. This was a random-number generator constructed by the London North-West Centre; Mr. Fudge was then invited to present the trophy to the winners.

The awards dinner was held at the Regent's Palace Hotel, Piccadilly Circus, where about a hundred members and guests enjoyed a fine meal which rounded off a very good day.

Two presentations were made during the evening. The first, on behalf of the National Committee, was made by the Chairman to the retiring President, Mr. K. Stotesbury, who was presented with a set of do-it-yourself tools to keep him busy during his leisure time.

The other presentation, also a retirement present, was to the Regional Liaison Officer to the Eastern Region, Mr. Turnbull. The presentation was made by Brian Puncher in recognition of Mr. Turnbull's past services.

M. E. Dibden
Secretary

Associate Section Notes

ABERDEEN CENTRE

The second half of the centre's programme was made up of 2 talks and 2 visits. Mr. W. F. Leith, a Head of Division in Aberdeen, gave a talk on *The Importance of Telecoms Development* and Mr. B. Sapsford gave a talk on *Measurement Analysis Centres (MACs)*; both talks were very informative.

An evening visit was arranged to the studios of a local independent television station, and day visits made to St. Fergus, which is the home of Total Oil Marine's gas collection terminal, and Peterhead, which is a new oil-fired power generating station. The centre's AGM ended the session; hopes were expressed that the 1980–81 session would be as successful as this last one.

We would like to take this opportunity to congratulate our colleagues in Inverness, who were the eventual winners of the national quiz competition.

J. H. McDonald

INVERNESS CENTRE

Last year's programme featured a visit to Savo Electronics, Inverness; talks on bridge building by a representative of the Cleveland Bridge Company, *An Introduction to Microprocessors* by Mr. D. Gaunt of the BPO Research Centre, *The Unit Digital Exchange* by Dr. P. A. Trudgett and Mr. M. J. Elsden of the BPO Research Centre; and a quiz between management and the Associate centre. Attendance for these meetings was up on previous years; indeed, this was the best session to date for the centre.

The centre's enthusiasm was most openly displayed by the success of its quiz team, which won the Scottish title for the second year running. The newly inaugurated Ness trophy was presented by Mr. Ness of the Scottish Telecommunication Board's Headquarters, who sponsored, designed and constructed the trophy.

The quiz team went on to further successes, with victories in the quarter finals against London and in the semi-finals against Preston. Finally, after a very close contest, the team emerged as victors in the National quiz against hat-trick seeking Oxford to gain the Bray trophy. The members of the quiz team were R. G. Swanson (captain), A. MacKenzie, J. Ogilvie, J. Fulton, P. Bisset and D. Ross.

R. G. Swanson

DERBY CENTRE

It is becoming increasingly difficult to find original industrial or technical venues to keep members interested in the activities of the Institution. This, and the fact that members are not always able to use leave for mid-week activities, gave the centre's committee an arduous task in planning the programme of events for 1979–80. Nevertheless, the committee succeeded in planning a programme, and high attendances proved that it was received with the enthusiasm it deserved.

During the summer, visits were arranged to the sand caves beneath Nottingham Castle and to a fire station in Ascot. In addition, a gliding evening at Ashbourne airfield was organized. Despite the fact that this event was not subsidized, it met with great enthusiasm; indeed, to the extent that another visit had to be arranged subsequently to complete the event. Because of its obvious success, a repeat of this gliding evening will most certainly be organized during 1980–81; the committee also feels that a ballooning trip might well meet with a similar response.

However, of all the events organized for the Derby centre, the visit to GEC at Coventry was the most successful. As well as the excellent hospitality they received, our 20 members enjoyed being shown the work which the GEC is doing for the British Post Office (BPO).

The centre's winter programme proved to be as extensive as that arranged for the previous summer. It began in October with a visit to the Shuttleworth collection of veteran aircraft and vehicles and, in November, continued with a day trip to the Science Museum in London. In December the centre held its annual social evening at the Kings Head, Duffield; it was very successful, and attracted a large number of members and their friends.

The year's programme finished with outings to the Derby *Evening Telegraph* offices in December and, in March, to British Rail's Technical Centre, where members were shown the more advanced techniques in signalling, safety and braking, and allowed to practice-drive a locomotive that had been placed on a fixed bed.

Besides the visits and outings that were arranged, the Derby centre has set up a library from which books about electronics, electrical engineering and many other technical subjects can be borrowed.

Having maintained its members' enthusiasm and interest during the past year, the centre's committee is now arranging the 1980–81 programme. Among the events envisaged for the coming session are visits to the BPO Computer Centre, to Humberside to see the centre of communication for the east coast coastguards and to a Derbyshire college of agriculture to look at the technology which is employed on many of Britain's farms.

K. W. Johnson

DUNDEE CENTRE

The 1979–80 programme started in October with a lecture on *Promotion Boards, How They Work*, which was given by Mr. I. Tait, Deputy Controller of Personnel, Scottish Telecommunications Board Headquarters.

In November over 120 members from various centres attended the Scottish Regional Lecture, given by Mr. D. Gaunt of the BPO Research Centre, on *An Introduction to Microprocessors*. The centre would like to express its thanks to Mr. D. B. McMillan, the Scottish Region Liaison Officer, for his help in arranging this lecture.

The year ended with a talk given by two of the centre's members, Mr. A. Bell, and Mr. G. Stewart, who gave the audience an excellent insight into the workings of the new repair service control centre at Dundee GMO.

In January there was a day visit to Walter Alexander and Sons, coachbuilders, of Falkirk, and in March the year's programme finished with a visit to the Scottish Horticultural Research Institute at Invergowrie. The centre held its annual general meeting in April.

W. T. Lindsay

Notes and Comments

Price of the Journal

The Board of Editors regrets that, because of increases in production costs and postal charges, it will be necessary to increase the price of the *Journal* to non-members to 80p plus 50p postage and packaging with effect from 1 January 1981. The corresponding annual subscription rates will be £5.20 (including postage and packaging); Canada and USA, $12. The price to British Post Office staff will remain at 48p per copy.

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The Post Office Electrical Engineers' Journal

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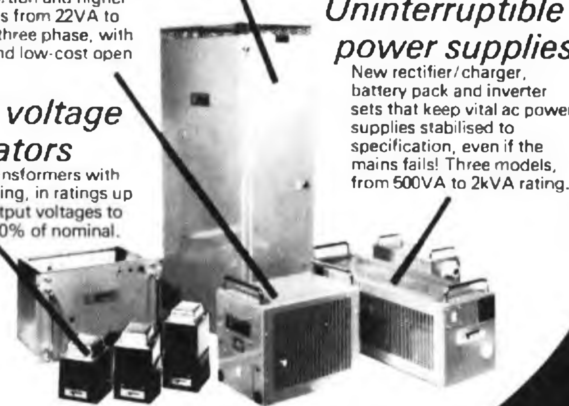

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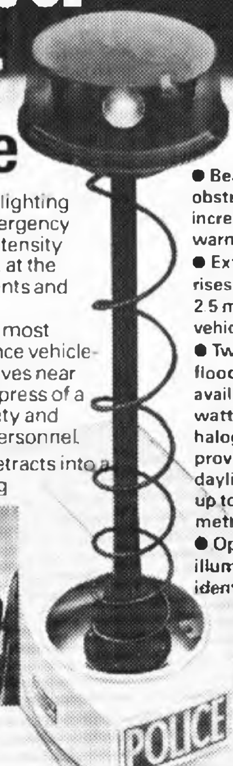

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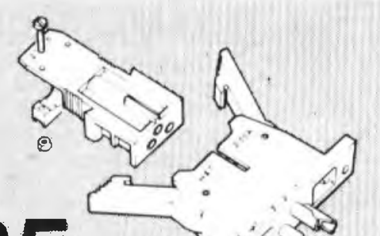

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