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Contents

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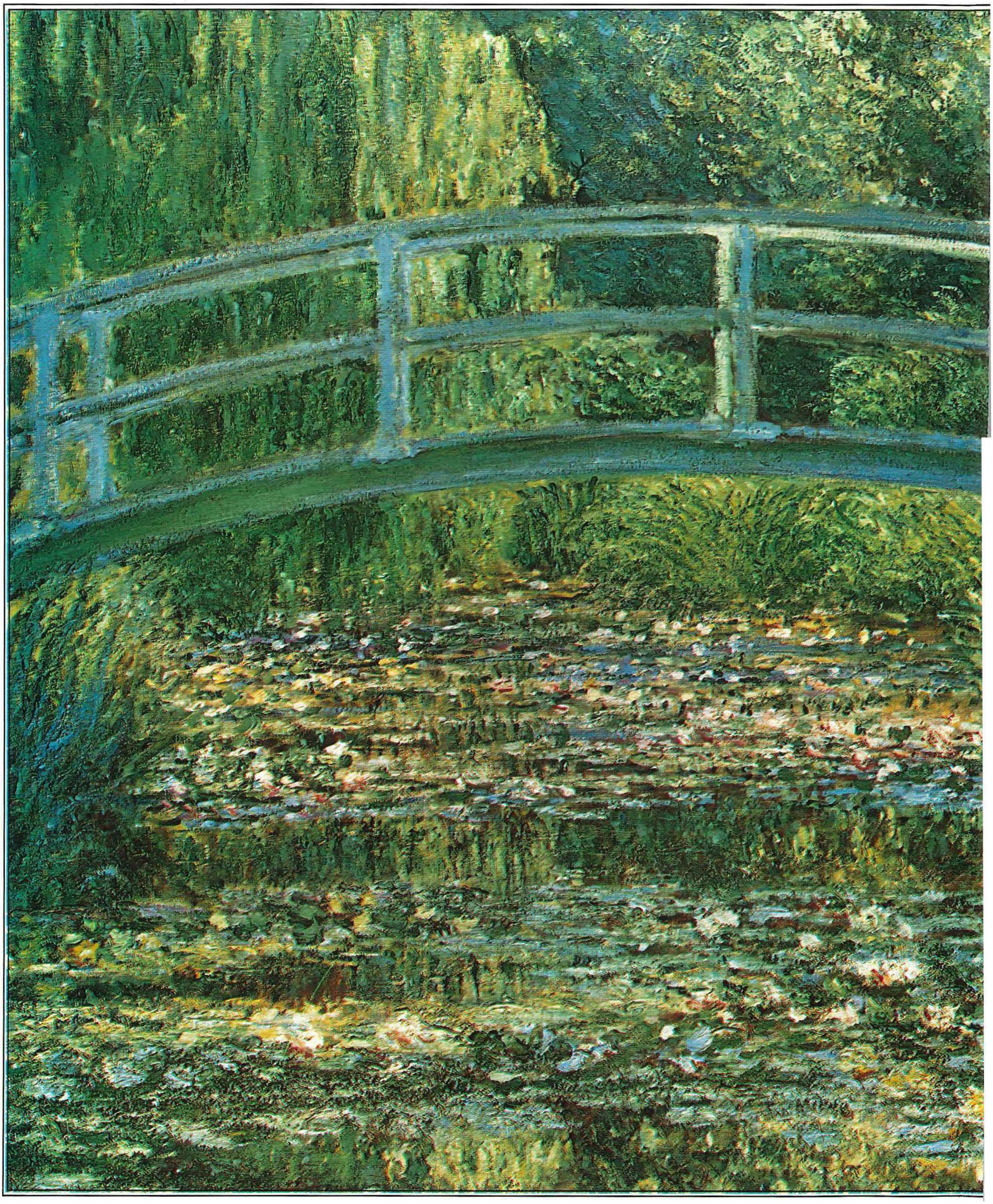
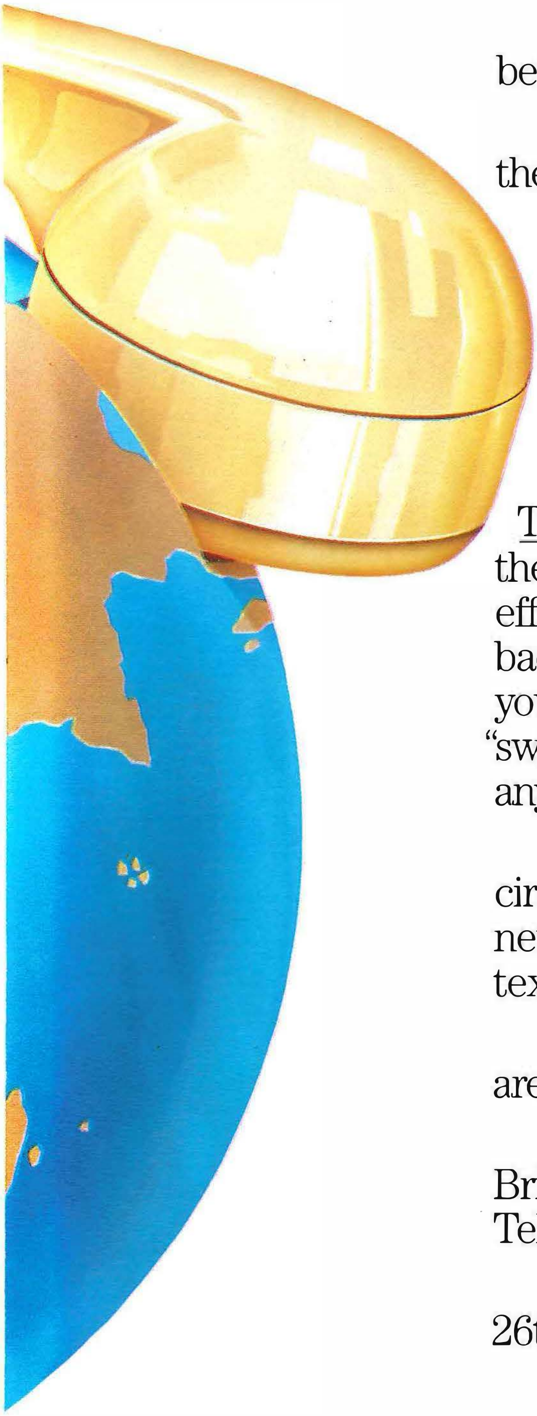


It's a British

Telecom world



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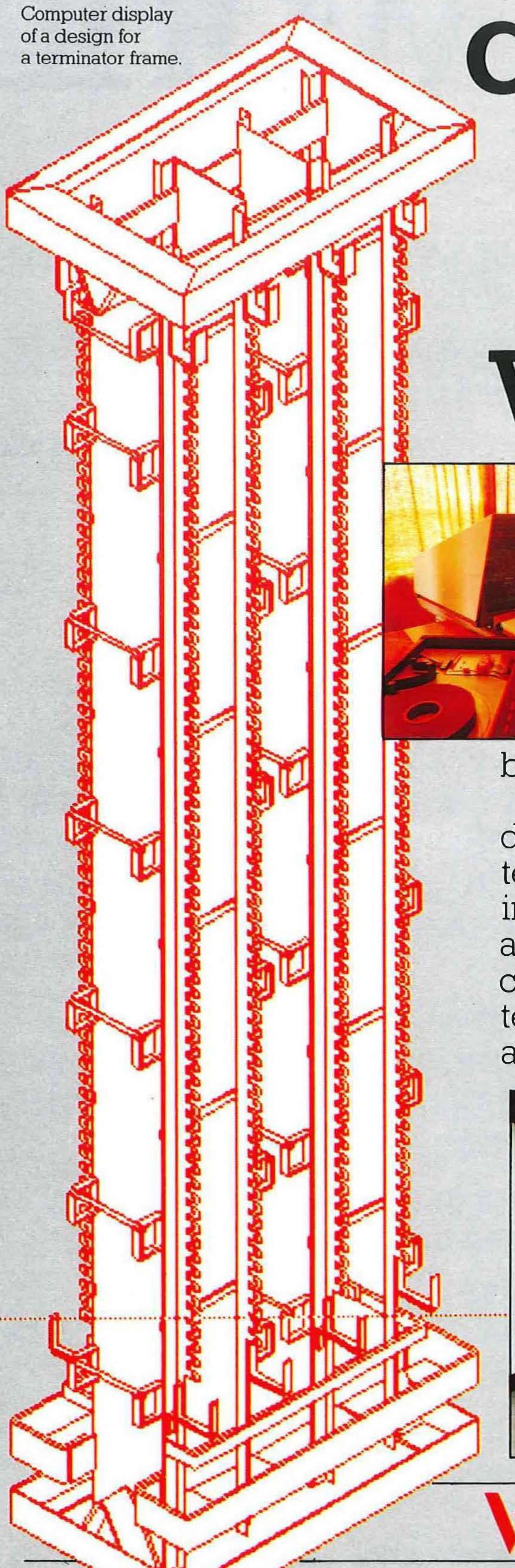
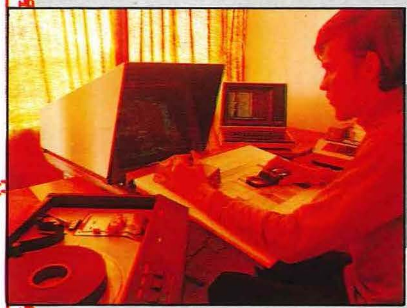
Computer display of a design for a terminator frame.



Computer aided engineering -a unique service from Warner & Sarll



At Warner and Sarll, we've taken the latest computer aided design (CAD) and computer aided manufacturing (CAM) techniques and brought them together to create our own unique brand of computer aided engineering.

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British Telecommunications Engineering

FOREWORD

This issue of your *Journal* is almost exclusively about British Telecom's (BT's) contribution to TELECOM 83.

From 26 October to 1 November 1983, the telecommunications world will meet in Geneva for this occasion sponsored by the International Telecommunication Union (ITU), an occasion that embraces a truly massive exhibition; a world forum for administrative, technical and legal subjects; a book fair; a film festival and other supporting features. It is the forum where all those involved in telecommunications around the world come to display their competence and to attract the attention of their customers.

This is the fourth time that the ITU has acted as sponsors. In 1971 and 1975, Britain was represented only in a few specialist areas; and only in submarine cable systems did we display world competence in a major product. In 1979, Britain stole the show. BT, Industry and Government put on a united front and left the world in no doubt that Britain intended, once again, to attack world markets, and that the drive would be launched from the market place of a modernised national network: a network based on international standards. The telecommunications world was left in no doubt about Britain's capability to design, manufacture and manage equipments and networks.

1983 sees BT, Industry and Government combining again in a British pavilion, but on a scale that dwarfs even our efforts in 1979. The accent now is on selling modern cost-competitive equipment, services, and ideas, with the emphasis on our experience in the telecommunications market.

What of 1983 to 1987? The future is in our hands—every one in BT, Industry and Government can make their own contribution. Excellence of design, competitive manufacture, intelligent marketing and forceful selling will bring rewards in every facet of telecommunications in Britain. We have the brains, and the experience, but we must find more consistently the application that produces the right product, at the right price, at the right time. Our aim must be to win on merit.

I have every confidence that Britain will hold its head high at TELECOM 83, and I thank all who have been concerned to make this possible. But we must not rest content that we have done well. We must continue to learn, digest and, where applicable, adopt the new ideas that will be on display. Only if we do this will we be able to provide our customers with equipment and facilities of an international standard and quality, and will the UK telecommunications industry, as a whole, thrive in the highly competitive international markets.

The changes in organisation and mangement now going on in BT are essential factors in making BT more successful in developing its business through meeting market needs. This market orientation will also encourage the UK supply industry to be a more competitive supplier thereby ensuring not only better sevice for our customers, but also helping too those companies to be more successful in competitive world markets.

Sir George Jefferson CBE
Chairman, British Telecom

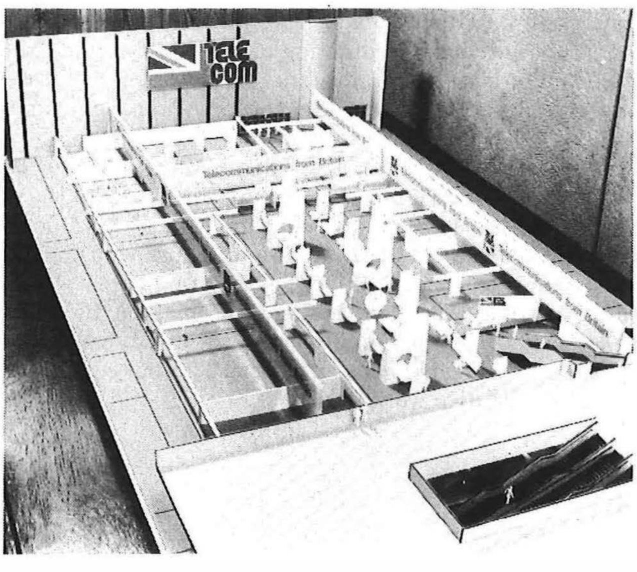
TELECOM 83: The Fourth World Telecommunications Exhibition

TELECOMMUNICATIONS FROM BRITAIN

The largest and most comprehensive display of British telecommunications equipment, systems and services ever to be mounted at an international exhibition will be on show in the British Pavilion at the fourth World Telecommunications Exhibition, TELECOM 83, which will be held at the *Palais des Expositions*, Geneva, from 26 October to 1 November 1983.

The British Pavilion will feature every aspect of modern communications, from digital switching and transmission techniques—including digital exchanges for rural areas, submarine cables, optical-fibre systems and satellite communications—to an integrated services digital network, embracing PABXs, data terminals and customer services.

The focal point of the whole British display will be the co-ordinated display of modern equipment and systems in the main fields of switching, transmission, rural communications and advanced services that is being presented by British Telecom (BT), and 5 major manufacturing companies: GEC Telecommunications Ltd, Marconi Communication Systems Ltd., The Plessey Company plc, Standard Telephones and Cables plc (STC) and TMC Ltd. The purpose of the co-ordinated display is to demonstrate the comprehensive capability of the telecommunications industry in Britain to serve the needs of posts and telecommunications authorities and other communications organisations, world-wide. In particular, it will emphasise how the British telecommunications industry can serve those administrations that are on the threshold of developing their networks and services from analogue to digital operation, and those that have a special interest in modernising rural communications.



Model of the British Pavilion for TELECOM 83

Surrounding the co-ordinated display will be the individual stands of the 6 organisations participating in the co-ordinated area, and beyond, but still within the British Pavilion, some 60 other organisations will be exhibiting under the aegis of the Electronic Engineering Association and the British Overseas Trade Board (BOTB). In addition, there will be a special external display area, of some 2000 m^2, where equipment including mobile earth stations will be shown in operation. Total British participation is under the sponsorship of the BOTB and will cover a total of nearly 6000 m^2.

For the first time, *British Telecommunications Engineering* will be presented on a stand at the book fair held in conjunction with the exhibition. This issue of the *Journal* is devoted to articles describing many of the products and services on show in the British Pavilion.

BRITISH TELECOM

BT's own stand will be divided into 3 primary areas: London as the centre of communications, office automation by BT, and BT's expertise in the planning, management and operation of networks. In addition, there will be a specialist area featuring submarine systems, and a high-technology area—the future with BT.

These areas will be supplemented further by 2 auxiliary areas: the combined activities of Telconsult and Teletrade, and the new BT, which will explain BT's new competitive status and the broad story of its competence in every branch of telecommunications, from digitalisation, network modernisation and the scale of network operation to the size and deployment of its investment programme.

The display will project the new image of BT as the operator of the UK's national network—one of the world's largest telephone networks. It will show how current and future development of national networks through digitalisation and optical fibre is making available new systems, services and products for national and international markets on a commercially-sound basis.

One objective of promoting BT's excellence and experience in the whole field of telecommunications is to encourage multinational organisations and overseas companies to centre their international communications in the UK, and London in particular.

By promoting BT's all-round ability to plan, manage and operate a variety of public and private dedicated networks, the display will also seek to create the opportunities for selling high-technology products, services and technical know-how overseas through Telconsult and Teletrade. Particular emphasis will be placed on this exporting ability since it increases the size of the market for BT's products, while generally improving the export opportunities available for the country's telecommunications industry and ancillary sectors.

London as the Centre of Communications

There is already a trend among the world's major businesses to regard the UK, with its excellent international communications links, as the world's telephone exchange. Nine of

London Telecom Tower

Japan's top trading companies have chosen London as their communications hub. BT's stand will encourage others to follow by illustrating the excellence of the national and international networking and the range of digital transmission systems it offers.

The stand will feature X-Stream digital services, the London Overlay network, which provides the transmission media to meet X-Stream requirements, customer services available through Overlay, and a selection of customer products designed for the digital era. Videoconferencing, with the latest terminals and a studio with a 2 Mbit/s demonstration link from the Geneva stand to the UK, will also be featured.

The leading element in this area of the stand will be the X-Stream family, which provides high-quality digital services on either a point-to-point (KiloStream, MegaStream and SatStream) or switched (SwitchStream) basis. The display will show how X-Stream services were introduced in the City of London on a digital network which overlays existing services, enabling them to be provided quickly.

One of the means of bringing the Overlay services network into customers' premises is 19 GHz digital radio, and one of the tools for interconnecting 2 Mbit/s streams of data to and from customers will be the 2 Mbit/s digital switch. BT will demonstrate these at the Geneva stand by using an electronic funds-transfer terminal operating over the international packet switching service (IPSS) and Packet SwitchStream (PSS). A range of KiloStream network terminating units will also be displayed.

PSS is an extension of the choice BT offers customers for data transmission. It is accepted as the main network solution where widespread standardisation and error-free communications are required using X25 protocols. The flexibility and availability of PSS make it useful for the majority of data applications, but it is most cost effective where transmission is interactive or of the transaction type; for example, point-of-sale terminals, credit verification, communicating word processors or for linking terminals to host computers.

Access between UK and overseas customers is provided by British Telecom International's (BTI's) expanding international packet-switching service (IPSS) which at present covers over 20 countries. This service also provides major international transit facilities for packet-switched traffic between other countries.

Another important development for PSS users is the Packet Netmux, which is installed, manufactured and maintained by BT. The Netmux is a large-capacity low-cost packet concentrator, packet assembler/disassembler (PAD) and switch, handling up to 32 asynchronous terminals and four X25 connections. The range can be extended by concatenation. It is intended to provide an economical solution to problems of interfacing specialised protocols with PSS and X25, to provide a low-traffic packet concentrator, a local packet switch and a remote PAD facility.

One of the early uses of the Netmux is the support of credit-card verification. The special terminals connect to Netmux, which provides concentration, interface to PSS and a special protocol support. This protocol was produced by BT with full consultation with the credit-card companies.

PSS is supporting gateways to other services. IPSS has already been mentioned. There is a gateway from Prestel which enables Prestel users to gain access via PSS to external computers.This is a one-way gate from Prestel to PSS and is particularly useful for real-time data information services such as home banking.

A gateway to the public switched Telex network, known as *InterStream 1*, connects PSS and Telex subscribers. Initially limited to the UK, it will shortly be expanded to cover international packet switching and international Telex.

Further gateways, particularly associated with the development of BT's Teletex service, are being developed. A full duplex and bidirectional gateway between PSS and the telephone service will be available shortly, followed by a conversion facility linking the telephone service, PSS and Telex to provide the total interconnection required for Teletex users.

KiloStream is BT's major digital private-circuit service. It offers business customers rapid provision of a digital link because of the advance provision of main network links.

Transaction telephone for credit-card verification

Rapid in this case means 15 working days. KiloStream is ideal for large companies or multinationals with heavy data-transfer needs, and the service will grow from 250 centres this year to 400 by the end of 1984.

Two types of this bulk data-handling service will be shown at the exhibition. The first is individually compatible with V24 and V35 interfaces, and the second works to the new X21 interface. Bit rates of 2·4, 4·8, 9·6 and 48 kbit/s structured with full circuit monitoring, or 64 kbit/s unstructured with in-built monitoring are available.

BT currently provides subchannelling equipment which can give up to 54 channels synchronous or isochronous, and asynchronous data. Important additions to the service are provided by Netmux K12 and K54, which give a wider choice of facilities; for example, the low-cost combination of speech transmission and a number of lower-bit-rate data circuits into a single discrete 64 kbit/s channel.

MegaStream is the highest-digital-rate private-circuit service in the X-Stream range. It can be tailored to 2, 8, 34 or 140 Mbit/s, but BT expects the main interest at Geneva will come from companies wishing to upgrade their analogue wideband circuits to thirty or thirty-one 64 kbit/s digital channels. The interfaces which BT will present—the CCITT† G703 or G732—can be used for connecting multiplexors, linking PBXs, accessing large data centres or video-conferencing.

The major attraction is the great flexibility in corporate networks which the 2 Mbit/s path offers, permitting peripheral PBXs, for example, to share central facilities, and this in turn gives rise to the possibility of a fully integrated digital network. A variety of multiplexors are also available for direct connection to MegaStream; for example, the Netmux K/M 54 provides up to 54 channels of mixed 32 kbit/s voice or data circuits with a comprehensive range of speeds and interfaces. Combinations of these multiplexors will permit customers to optimise their networks in the most cost-effective manner for both data and voice.

The MegaStream wideband service can be connected directly to modern digital switchboards or to computers for direct computer-to-computer high-speed data transfer.

The fourth private circuit service of the X-Stream range is SatStream. This small-dish satellite service, generally available next year, will offer integrated and flexible digital transmission facilities for intra-company networks.

SatStream will offer businesses private digital integrated communications within the UK and between European countries and North America. Access to the satellite will be via small-dish earth terminals located on a customer's premises for his sole use, or via a community terminal close by for shared simultaneous use by several customers. Road-transportable terminals can be used to set up temporary or urgent links anywhere in the country, even at short notice. SatStream will offer speeds of 2·4 to 64 kbit/s, and selected multiples of 64 up to 1920 kbit/s, enabling one-way point-to-point, two-way point-to-point, and one-way point-to-multipoint transmission.

Satstream will be particularly suited to: point-to-multipoint applications; serving customers who have data communications requirements; meeting demand for the rapid expansion of redistribution of capacity within private networks; and providing temporary and urgent communications facilities to business centres as well as remote locations, including oil platforms. The last application should interest oil production and exploration companies from many countries.

The stand will contain exhibits showing BT's awareness of the rapidly changing field of information transfer, and the evolution of a new range of stored-program control (SPC) new range teleprinters, Telecom Gold electronic-mail services, Bureaufax—the international facsimile service—and a comprehensive Teletex service.

†CCITT—International Telegraph and Telephone Consultative Committee

Road-transportable small-dish earth station

Telecom Gold

The emphasis here is service to the customer and the international nature of the services available, such as the international leased telegraph message switching (ILTMS) and international private leased circuits (IPLC) services.

Slow-scan television, Teletrade's City Business System, and advanced developments in Prestel will be shown in action, and where feasible the hardware will come from the Merlin range marketed by British Telecom Enterprises (BTE). The information transfer services will combine to use one executive workstation and one new generation teleprinter working to the hardware for ILTMS to demonstrate that BT's modular approach to communications needs means that a single workstation performs many disparate functions with ease and efficiency.

The customer products area of the stand will emphasise that BT's customers have a wide range of choice of connection to a network designed to support whatever new services and modern equipment the customer needs.

Despite the massive upsurge in digital data applications, the bulk of communications in most of the world's city offices is still carried by analogue telephones connected to lines using analogue transmission.

BT will display its range of modern telephones and other advanced equipment in the BTE Merlin and Consumer Products ranges, including the Trent, Tyne and Medway callmakers; the Falcon and Eagle answering systems; and the Puma, Cheetah and Sable 'super Telex' Merlin teleprinters.

The objective is twofold: to illustrate what BT can already provide to enhance existing networks; and to show the modern equipment sponsored by BT that can be purchased overseas through Teletrade.

A new videoconferencing system, using 2 Mbit/s digital links, can be used in the normal committee rooms at company locations and obviates the need for a fully-equipped studio. The system increases flexibility and reduces costs to a level where businesses can have videoconferencing installations on their own premises.

Various camera and monitor options are possible. A compact desk-top unit incorporates both face-to-face and document/object display facilities. A free-standing cabinet terminal combining a face-to-face camera and 2 full-size colour or black-and-white monitors is also available. Another camera can be attached to a stand or to the ceiling to enable documents or objects to be displayed with ease.

The room need not have the powerful lighting of a TV studio: conventional office lighting is suitable. The acoustic treatment of the room is minimal and, apart from bright or glaring surfaces and patterned fabrics being avoided, the furniture is the same as that of any normal meeting room—except that the people meeting are kilometres apart.

Falcon answering and recording machine

Videoconferencing

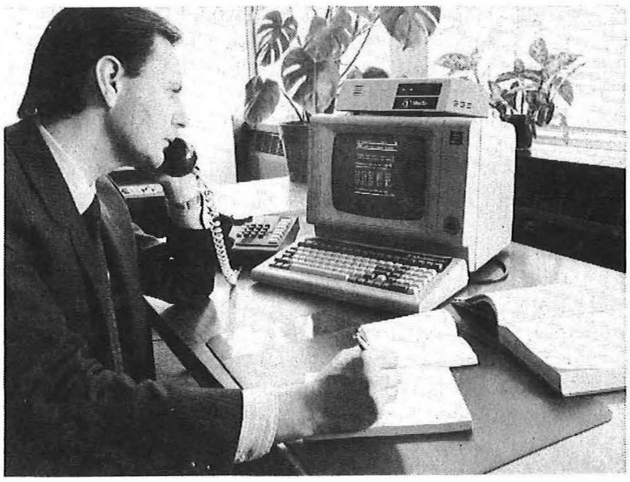
Office Automation Systems

Another important element of BT's stand is office automation systems. BTE is developing a modular system of Merlin terminals and interface units to enable customers to automate their offices in stages and increase the range of services that can be accessed when the need arises.

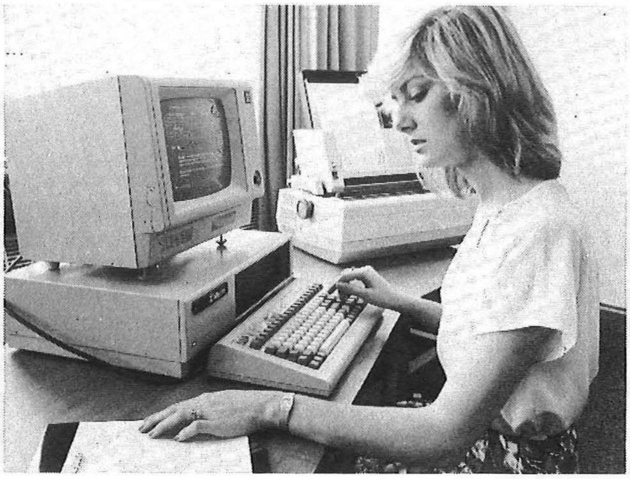
Customers will be able to purchase a complete package to meet their immediate needs, additional packages as their needs change. These modules and packages, marketed as Merlin products, can be used extensively not only in London, but also elsewhere. The display will therefore put across the message that they are available anywhere in the UK.

BTE will be continually updating, improving and extending the Merlin office packages and modules on offer. By October there will be a number of office-system products including a high-quality word processor and a range of small business computers—all with Telex and data communication facilities.

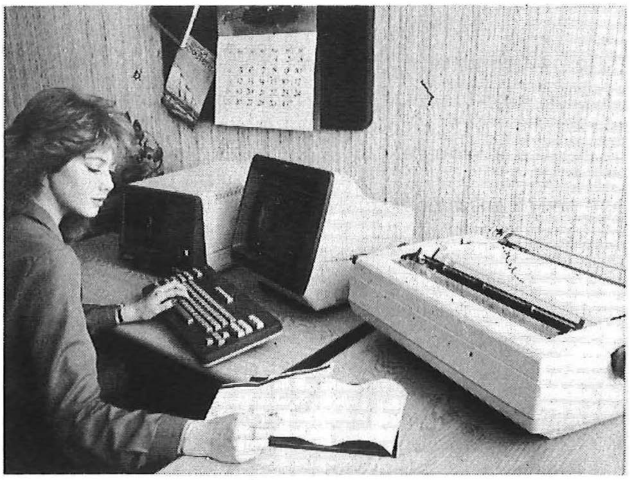
The packages currently range from the M1100 desk-top visual display unit (VDU) coupled to a relatively intelligent Merlin modem interface unit. The M1100 can organise dial-up access over the public switched telephone network (PSTN) to services such as Prestel, PSS proprietary databases, Telecom Gold's electronic mailbox service, and a host of other remote data stores. A hard-copy printer can be associated with the VDU.



Merlin M1100 desk-top VDU and modem



Merlin M2226 small business computer



Merlin M3300 communicating word processor

The M2226 small business computer has the ability to access private and public databases at the touch of a button, and to send and receive messages using a computer-based message service such as Telecom Gold. It uses a more sophisticated and intelligent Merlin modem known as *MICRO.*

The MICRO couples to other interfaces to provide a much wider range of services. These would include all those offered on the first model, together with the additional interfacing to the national and international Telex services, via dumb modems to the various Datel-type services on the PSTN or on private circuits, and full interconnection to Teletex.

Merlin's M3300 communicating word processor completes the initial range. It offers the option of press-button access to the Telex network and automatic dialling to remote databases, computer bureaux, Prestel and electronic mail services. The system can handle a variety of office formats and can perform complex calculations. As well as the usual word-processing functions, the M3300 can handle all kinds of office forms, columns, diagrams, flow charts, and newspaper layouts—ideal for composing, editing, distributing documentation and updating regular office reports.

Network Administration

A further theme of BT's display centres on the planning, management, operation and promotion of networks. This section will promote BT's ability, through Telconsult, to provide assistance for any of the responsibilities of an overseas communications administration.

The display will deal with the issues involved in planning a network, with particular reference to digital networks and the conversion from analogue to digital transmission. Specific examples of planning practices will include traffic measurement using portable traffic-recording equipment; cable performance measurements with the digital crosstalk analyser; planning rules for digital lines, and aids for junction network design.

Managing and operating a network is a daunting task. The performance of the network must be monitored, and faults must be reported, detected and corrected. BT's competence to advise on such problems will be shown by demonstrations of the building services management system, the repair service centre organisation, the remote line testing system and the building distribution system with Rapide plug-and-socket connections to customer equipment.

BT will impart the message that 'an under-utilised communications network is a wasted asset'. For a large part of each day some areas of the network are under used. The promotion of services to improve use will include Radiopaging, the Solent alarm system, ABC alarms, recorded announcements and aids for the handicapped.

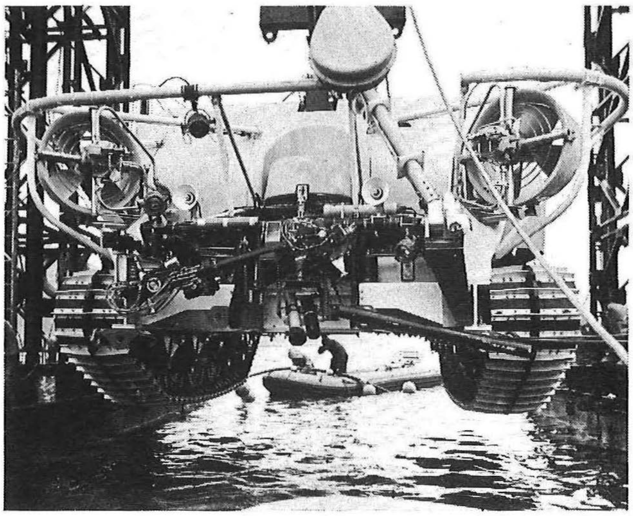
Submarine Systems

Submarine systems have been brought together to form the specialist area of the stand, which will deal with such issues as development, planning, installation, commissioning and maintenance. BT's very wide involvement and expertise in practice and in offering consultancy services will be highlighted.

Examples of BT's current involvement in development will be through displays of designs of cable joints and cable fault location equipment, the development of lightweight cable by using optical fibre, and cable testing machinery. Examples of new designs of fibre, cable and jointing techniques will be on display.

BTI has the capability to plan any and every aspect of a submarine cable system anywhere in the world. It can install and commission every component of a submarine system from cable station to cable station, including laying shore ends, shallow-water sections (and burying the cable if required) and deep-water sections. It can also provide the testing techniques that ensure the system has the required overall performance.

A demonstration model of a remotely controlled tracked vehicle, developed by BTI, which can operate in depths down



BTI *Seadog*

to 150 fathoms (274 m) to bury, inspect and aid the repair of submarine cables will be displayed. Operations are controlled from one of BTI's 3 cableships, which lay and maintain 30 000 km of cables around the UK coast and out across the Atlantic.

The Future with British Telecom

The final part of the exhibition looks to the future, and points out that the hardware on display is just one element of the broad spectrum of research and development undertaken by BT.

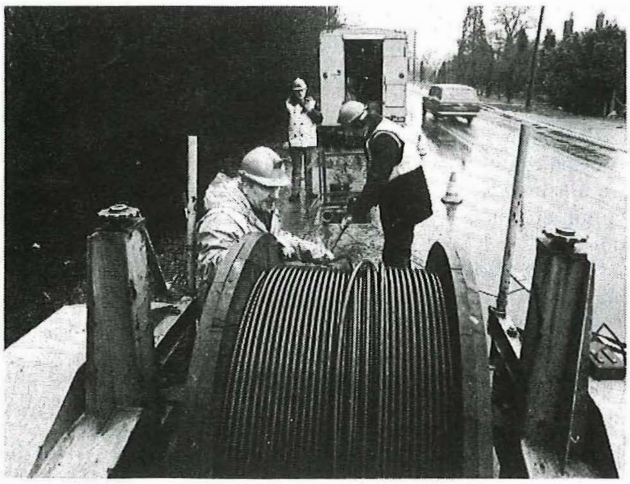
With optical-fibre systems as the centrepiece, this area of the stand will emphasise the scale and quality of BT's research and development effort, and its continuing dedication to the future. BT has a world lead in optical-fibre technology in terms of bit rate times regenerator spacing, and this is an important factor in the cost of transmission. The greater the spacing between regenerators for a specified bit rate, the lower the cost of the system. The display will underline the important feature that optical-fibre technology applies to both land and submarine systems. Elements of an optical-fibre call transmission system will be shown, and indications given as to future developments.

Every transmission system, both on land and undersea, must have a fault location capability. It is essential to detect faults quickly and accurately and, where possible, to detect trouble before it affects customer service. Fault location in optical-fibre systems has been made easier on land by the development of a photon-counting optical time-domain reflectometer. This piece of equipment is a kind of optical radar, with faults registering in varying forms on the screen. The equipment is also capable of evaluating optical-fibre jointing, and in both cases locates the fault and quantifies its extent and nature.

Very accurate butt jointing of the hair-thin glass fibres is required to keep the transmission losses at joints to a minimum. Despite the difficulties, techniques have been developed to do the job, and they are now being successfully transferred from the laboratory to the manhole.

BT is among the world leaders in optical-fibre jointing techniques and equipment, and a working jointing machine will be displayed on the stand at Geneva.

Overall, BT's display at Geneva sets out to present a balanced picture of what it can offer customers today, and its capability for the future. By promoting its excellence in the whole field of telecommunications, BT aims to encourage the world to bring its communications business to the UK, and to create opportunities for selling expertise and products overseas.



Optical-fibre cable laying in the field

MARCONI COMMUNICATION SYSTEMS LTD

A major feature on the Marconi Communication Systems stand will be a broad range of 64 kbit/s digital network equipment. This equipment is being used by BT to provide KiloStream.

The equipment provides standard interfaces for a wide range of data rates up to 64 kbit/s, using a network time-slot as a bearer. The use of 64 kbit/s in this way enables voice services to be integrated with data, and allows integrated services digital network facilities to be introduced as and when they become available.

The range of equipment covers computer-controlled cross-connection equipment for routeing and network organisation, 2 Mbit/s primary multiplex with full time-slot access, local line systems for 64 kbit/s transmission over physical telephone connections, and time-slot sub-multiplexing equipment for speech and data.

THE PLESSEY COMPANY PLC

Plessey will be exhibiting a wide range of products, demonstrating the company's competence over a wide range of advanced technology in communications.

Plessey Telecommunications Ltd. (PTL) is the prime development contractor for System X, the new British digital telephone exchange system. This system, together with a working model of a small rural exchange (UXD5B), will be a main feature on the Plessey stand. PTL, as a world leader in digital transmission systems and, in particular, optical-fibre systems, will be showing a number of working terminals. Among other exhibits, PTL will be displaying working models of payphones and modems.

Plessey Controls Ltd. (PCL) will be exhibiting a new family of advanced digital data circuit switches. Designated the *Plessey 8600 series*, this range is designed to meet the exacting requirements of public network Telex and Teletex switching, where sophisticated facilities such as store and forward and the ability to interwork with packet-switched networks are required.

Plessey Radio Systems (PRS) will be launching their 13 GHz equipment, and the products exhibited will cover a wide range of applications at 2·048, 8·448 and 34·368 Mbit/s, and are totally compliant with CCIR†/CCITT Recommendations. Various mechanical configurations are being shown, including rack-mounted equipment in TEP1E practice, and integrated 'rooftop' equipment.

The main feature of the Plessey Office Systems Ltd. (POSL) exhibit will be the Plessey IBIS electronic office, built around the new third-generation integrated digital exchange (iDX), and this will illustrate the integrated handling of voice, text and data information. Also on display will be a comprehensive range of telephones, featurephones, display telephones and workstations, key systems and the CDSS range of digital PABXs. Plessey's capability in remote interrogation, management and maintenance will also be illustrated.

STANDARD TELEPHONES AND CABLES PLC

STC will illustrate how its new office automation system allows existing familiar business equipment, such as computers, printers, Telex terminals, visual display units and word processors, to communicate. They will also be able to access the system's new services like electronic mail, diary, filing, etc., without affecting their current use. The display will feature STC's latest range of business products, including an OCS 300 digital PABX, intelligent telephone and terminals, Perfector 3000 Telex terminals with text-editing capability, a 6100 text communications system with Telex interface, Scribe word-processing equipment and data communications equipment and peripherals.

† CCIR—International Radio Consultative Committee

Another feature of the stand will be a display of STC's interactive video capability. This will be a demonstration of broadband transmission and switching showing, in addition to a choice of television channels, a video telephone, a 'moving' mail order catalogue and home electronic funds transfer facilities.

The latest monomode optical-fibre cable systems are being demonstrated by STC in 2 main displays. One is a short haul 280 Mbit/s undersea cable link and the other is a 140 Mbit/s land-line system. STC will also be showing a new transmission transmultiplexer for the first time. This provides bidirectional conversion between 60 frequency-division multiplex and pulse-code modulation channels.

Products that provide more efficient use of telephone networks receive special attention from STC. They include Datex 90, a system for carrying data around telephone networks without inhibiting telephone traffic; and Extraphone equipment for installing 2 independent telephones on the one subscriber line. ABC alarms offer a similar concept: they link sensors for fire, intruder, temperature etc. to relevant monitoring agencies (police, fire service, private security organisations) over existing telephone lines, while still allowing normal use of the telephone. Other displays include STC's Telecheck charge card authorisation terminal, equipment for eliminating echoes from international long-distance telephone calls, new electronic telephones, wide-area radiopagers and optical and remote line test equipment to check the telephone network from a desk or console at a central location right to individual subscribers' lines.

In the outdoor area of the exhibition, STC will be operating a Mascot 2000 ships satellite communications terminal complete with radome-housed antenna.

TMC LTD

TMC will be demonstrating their full range of hybrid small business communications systems, including KBX3, KBX6, KBX10 and the new KBX100B. The KBX range of systems is fully complementary in terms of capacity, and offers sizes from 1 exchange line and 3 extension lines (in the case of the KBX3) up to 100 ports (in the case of the KBX100B).

All these systems offer a comprehensive range of facilities and features, and the new KBX100B (now being supplied to BT as the *Herald 100B*) provides an additional range of operator features, extension features and system features, including operator override, external conference and call logging.

The full range of KT electronic press-button telephones will also be demonstrated. Included in the range is the KT1 instrument, supplied to BT as a standard telephone known as *Statesman*. Other instruments featured include multi-frequency versions, autodiallers, facility telephones for use with KBX3 and KBX6 systems and featurephones, such as the KT20, which provide multi-functions through any electronic PABX.

In addition to the range of telephone instruments and systems, the new supplementary services unit (SSU), now being installed in BT's main exchanges, will be demonstrated. The SSU is a front-end processor which upgrades the performance of an electromechanical exchange to provide added-value services equivalent to those available from an electronic stored-program control exchange.

A new development in the field of transmission will be demonstrated on both the TMC stand and in the co-ordinated area of the British stand; this is the 1+1 Transmission System, which provides either 2 speech paths over a single telephone pair or a combination of one speech path and one data path over a single pair.

GEC TELECOMMUNICATIONS LTD

GEC will be demonstrating its total capability in advanced-technology switching and transmission systems for national telecommunication networks.

A comprehensive product range includes System X, the new British digital switching system which embraces all requirements from small local to international gateway exchanges. GEC is a founder member of the team that developed System X and is fully committed to its ongoing development, large-scale production, and international marketing.

For small remote communities, the UXD5 unattended digital exchange is fully compatible with the System X family of exchanges and can therefore operate in both digital and analogue networks. The UXD5 is established in service in the UK and has attracted a number of overseas customers.

GEC is a leading manufacturer of both low- and high-capacity transmission systems for digital and analogue environments. Digital systems include a complete hierarchy of multiplex equipment up to 140 Mbit/s, microwave-radio systems, optical-fibre and coaxial cable systems and 30-channel pulse-code modulation systems.

Analogue systems with frequency-division multiplex equipment from 12–2700 circuits include microwave-radio systems, coaxial cable and 12-circuit carrier line systems and a range of data modems.

Of particular interest is an enhanced version of the UXD5 digital exchange that incorporates a 2 GHz 8 Mbit/s microwave-radio system in the same cabinet. The GEC UXD5/2 GHz package is an economic stand-alone digital system for small-capacity rural and suburban communications.

GEC Information Systems is exhibiting, for the first time to world markets, the *LYRIC* digital PABX. An evolutionary development of the BT Monarch project, in which GEC is a major partner, the LYRIC fully digital voice/data PABX caters for up to 250 lines. It is a key element of GEC's approach to advanced business communications technology (larger capacities are served by the established SL-1 system).

Another new, and exciting, product is *DATACOM*, which combines a visual display unit and featurephone. It comprises a 12 inch display with a separate 'QWERTY' keyboard and a full-function telephone. The unit uses an INTEL 8088 microprocessor and provides a wide range of advanced telephone and data functions including 80-column data access, viewdata support and directory enquiry.

Another product seen for the first time at Geneva is GEC's *ECHO* voice store-and-forward system, whereby voice messages are spoken into and digitally stored by ECHO under microprocessor control and via any conventional telephone and, of course, the new DATACOM. The messages are reconstructed later on demand and transmitted as the original voice to any number of destinations at any time.

GEC has on display real-time computers (including the new 63 series and the GEC 4000 series) for a wide variety of applications including communications networking, satellite communications, radiopaging, videotex, Teletex and information systems. GEC computers are being used for satellite communications in Project Universe, the British satellite system for high-bandwidth transmission of data between computers.

Telecommunications, computers, local-area networks, information processing, word processors and workstations are all integrated with combinations for GEC PABXs and computers, using international standards such as Teletex and X25.

GEC is also exhibiting the *CENTEX* Teletex server. It enables Teletex to be accessed from any conventional data terminal (and any devices such as the GEC DATACOM) by direct connection or through a PABX.

Also featured is a comprehensive range of telephones and business communication systems for the small organisation. There are 6 small-capacity systems in the GEC range, from the GEC 13 (one exchange line and 3 extensions) to the GEC 520 programmable electronic keysystem (5 exchange lines and 20 extensions), all with many facilities normally found only on larger PABXs.

Protection of Submarine Cables

P. VINCENT-BROWN T.ENG(C.E.I.)., M.I.ELEC.I.E.†

UDC 621.315.28 : 621.315.22

This article highlights the growing hazards to submarine cables, particularly from fishing activities, and discusses methods of protection. Cable armouring is compared with cable burial in terms of cost and effectiveness. The article concludes with a description of cable burial methods.

INTRODUCTION

Submarine cable systems form a vital link in the global communications network and considerable emphasis is placed on their reliability. For example, the engineering reliability standard applied to the design and manufacture of repeaters is a mean-time-between-failure for all the repeaters in a system taken together of 10 years during a 25-year life. This quality of engineering will be ineffective if the cable is inadequately protected against the environmental hazards of its location on the seabed.

Since the mid-1960s, considerable effort has been directed at cable protection, either by overarmouring of cable, or by cable burial. The emphasis in this article is on British Telecom (BT) activity as it relates to the protection of systems landing in the UK, and to those for which British Telecom International (BTI) is co-owner and/or has joint maintenance responsibility.

Generally, in water depths in excess of 1000 m, no protection is given to cable other than that afforded by its polyethylene sheath. In shallower water, protection is achieved by using cable having one or two layers of helically-wound steel armour wire over the cable sheath. Alternatively, cable burial may be recommended. A decision on the method of protection is made after detailed planning has identified the best route and the protection measures necessary to minimise the effect of tidal abrasion, ships' anchors and fishing activity. The choice of landing site is often dictated by other network constraints; consequently, it is not always possible to avoid environmental hazards. More recently, greater consideration has had to be given to the activities of offshore oil and gas industries, and the effects of their plant on cable routes.

Burial has been applied to intercontinental systems where economic considerations, including the implications of re-routeing and network security, provide adequate justification. For continental systems, where the cost of burial could not be justified, protection of cable has been achieved by the use of armouring as directed by the route planners. Additional service protection is achieved by providing sufficient spare capacity to carry the circuits lost if any single cable fails, thus facilitating the temporary restoration of service over alternative routes.

PHILOSOPHY AND ECONOMICS OF CABLE BURIAL

Cable Protection

Protection techniques have been applied since the 1960s and are current practice. However, over the years, a number of trends have caused cable burial to become an increasingly attractive method of protection. It became evident that the existing range of armourings was not providing adequate protection against fishing activity. In the North Sea, for example, the fault situation became worse when beam trawling was re-introduced in 1958. Subsequent development of beam trawls and trawlers have led to heavier trawls, operating from more powerful trawlers, with greater potential for damaging submarine cables. In 1958, the mean power of trawlers in the North Sea was 142 kW (190 hp), but in the decades that followed, it rose to 283 kW (380 hp) and 970 kW (1300 hp) respectively. This increase in trawler power was followed closely by an increase in faults arising from fishing activity.

TABLE 1

Comparison of North Sea Cable Faults arising from Environmental Factors

Cable Type	0·620/15·75 (inch/mm)	0·935/23·75 (inch/mm)	1·47/37·3 (inch/mm)
Core diameter (mm)	15·7	23·7	37·3
Armour diameter (mm) type	35·0/E	42·0/E	61·0/E
Maximum strength (MN)	0·22	0·28	0·41
Fault category (percentage)			
Trawler break	55·3	43·8	0
Trawler cut	3·7	6·9	23·1
Trawler maul	11·1	40·0	28·2
Pulled joint	0·8	2·3	2·6
Cause unknown	21·7	3·8	20·5
Anchor break	7·4	3·2	25·6

Notes: 1 E armour uses 2 galvanised mild-steel wires, 7 mm in diameter.
2 Trawler cuts are faults where the cable has been cut with a hacksaw, or flame torch.
3 Trawler mauls are shunt faults where the inner conductor is exposed to the sea, but otherwise remain continuous.
4 Although only in limited use at present, rock-armoured sections have suffered no faults.

Table 1 summarises the faults on the 3 sizes of cable in common use in the North Sea and represents a typical distribution of failure modes arising from environmental influences. At least 75% of all faults were probably attributable to fishing activity.

Approaches to combat the worsening fault situation were aimed at 2 areas. The first was directed at the fishing industry. It consisted of an extensive publicity and information campaign on submarine cables, their location in the sea, and the procedures for compensation for the loss of abandoned fishing gear ensnared in submarine cables. Attempts were also made to encourage the modification of trawling gear to reduce the hazards to submarine cables.

The second approach was a joint development programme, by BT Research Laboratories and Standard Telephones and Cables plc (STC), of cable armouring. This culminated in the development of an armouring that is resistant to trawl fishing, consisting of a layer of conventional helically-wound armour wire, over which is applied a short-lay spiral armouring. Fig. 1 illustrates the armour arrangement on a 37·3 mm cable. Since short-lay armour had previously been used to resist rock abrasion and iceberg crush, the name *rock armour*

† Marine Service , British Telecom International

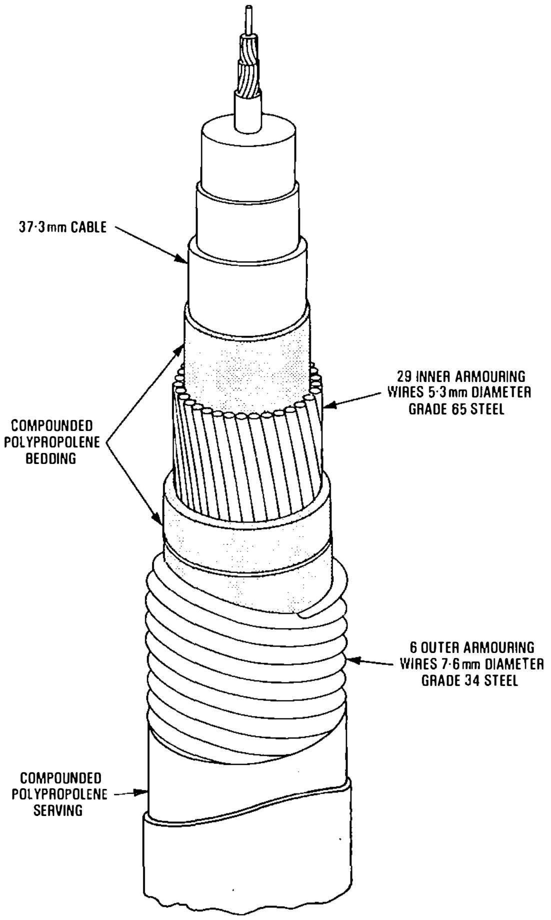


FIG. 1—Rock armour cable

has been retained. Closely-wound rock armour prevents the inner layer of conventional armour from being opened by the rotational force exerted on the cable when impacted by trawl gear; in this way, it protects the cable from trawl damage.

Effective as it is, rock armour is designed primarily to protect against maul faults (that is, shunt faults where the inner conductor is exposed to the sea, but otherwise remains continuous), and its ability to protect against other failure modes has yet to be established. Since its development, it has been specified for, and installed in, a North Sea system in 1979. To date, there have been no faults in the sections concerned, although all are in areas of fishing activity.

The disadvantages of rock armour are its considerable weight and stowage requirements, and its cost—typically, an additional 60% per unit length on conventional single-armour cable costs. It is now generally accepted within the British submarine cable industry that further developments of armouring are impractical and uneconomic.

Cable Burial

As a marked contrast to the fault history of unburied cables, that of buried cables has proved to be very acceptable. Table 2 details the cable sections buried to date, with subsequent fault incidence on these sections. In all, some 1100 km of cable have been buried over the period 1967–76, with a further 460 km to be added to this total on completion of TAT 7 in 1983.

To date, there have been 9 faults, of which 5 have occurred as repeat faults. These are believed to have arisen because the first repair operations left sections of cable lying on the surface of the seabed and, therefore, vulnerable to further damage. No post-lay burial device was available at the time to re-bury the exposed cable. Overall, the clear indication is that, given a stable seabed, burial is the best form of protection.

The additional cost of enhanced protection offered by burial can be justified more readily for systems with high circuit capacity, because failures of these systems are liable to cause unacceptable network congestion. The circuit capacity of individual submarine cable systems during the last 30 years has risen from 60 circuits in the late-1950s to 6000 circuits in the mid-1980s. The high circuit capacity of modern systems emphasises the need for enhanced protection and tends to justify the higher costs involved.

As there are no cases where direct comparisons can be made, it is difficult to assess the relative value of double, or rock armour against burial as a means of protection. However, on the basis that burial generally affords better protection than armouring, an upper cost limit for burial can be set at the cost of applying the best armour protection to that length. It is BT policy to apply a single armouring to cable prior to burial, and this will continue until a method of recovering buried unarmoured cable is perfected. Hence, for BT, the upper cost limit of burial may be considered as that required for overarmouring a single armour layer with rock armour; that is, an additional 60% per unit length on conventional single armour costs.

Fig. 2 illustrates typical costs of the most commonly used 1·47 in (37·3 mm) cable without armouring, with rock armouring, and with a combination of single armouring and burial. It can be seen that there are initial fixed costs associated with burial resulting from mobilisation and demobilisation of equipment. As a consequence, rock armouring is a more economic method of protection for lengths of cable up to approximately 10 nautical miles (19 km); beyond that, a combination of single armouring and burial provides a more attractive economic solution.

FISHING METHODS AND THEIR INFLUENCE ON DEPTH OF BURIAL

The principal methods of bottom fishing are otterboard and beam-trawling. Both methods are designed to catch fish that dwell on or about the seabed.

An illustration of otterboard trawling is given in Fig. 3. The trawler drags massive otterboards or doors along the seafloor, one at each side of the catch net. The mouth of the net is kept open by buoying the top and weighting the bottom. The otterboards are steel edged and can weigh as much as 4 t. During trawling, they can penetrate the seabed by as much as 40 cm, fouling and damaging cable as they attempt to traverse it.

The beam trawl is illustrated in Fig. 4. It consists of a

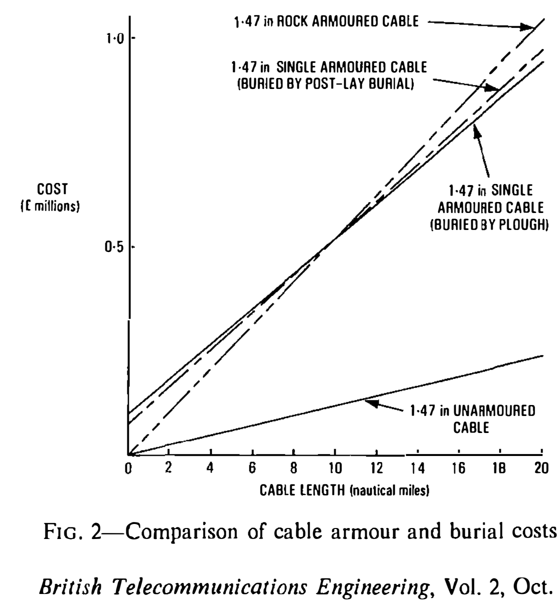


FIG. 2—Comparison of cable armour and burial costs

TABLE 2

Buried Cable and Fault History

System Terminals	Sections Buried Cable Types/Lengths km (nautical miles)	Depth m (fathoms)	Burial Date	Faults
TAT 4 USA side (USA–France)	R3–R5 Lightweight 70 (38) Armoured 4·5 (3)	47–139 (25–75)	1967	No faults recorded
TAT 3 USA side (USA–UK)	R2–R5 Lightweight 85 (46) Armoured 3·0 (1·5)	37–148 (20–80)	1967	No faults
TAT 4 French side (USA–France)	R180–R181 Lightweight 17 (9) Armoured 3·0 (1·5)	148–167 (80–90)	1970	No faults
	EQ18–R182 Lightweight 11 (6)	148 (80)	1970	One fault
	R182–R183 Lightweight 37 (20)	130–148 (70–80)	1970	Three faults
	R183–R184 Lightweight 44 (24)	111–130 (60–70)	1970	Three faults
	R181–EQ18 Lightweight 11 (6)	159 (86)	1970	No faults
	R184–R185 Lightweight 37 (20)	65–111 (35–60)	1970	No faults
	R185–R186 Lightweight 28 (15)	37–65 (20–35)	1970	No faults
TAT 3 UK side (USA–UK)	R177–R182 Armoured 144 (78)	46–111 (25–60)	1970	Two faults
CANTAT 2 Canadian side (Canada–UK)	R473–R471 (partially ploughed) Armoured 22 (12)	15–104 (8–56)	1972	No faults
	R471–R449 (fully buried) Armoured 76 (41) Lightweight 167 (90)	104–122 (56–66)	1972	No faults
TAT 6 USA side (USA–France)	R1–R22 Armoured 167 (90)	19–463 (10–250)	1976	No faults
TAT 6 French side (USA–France)	R673–R690 Armoured 174 (94)	155–222 (84–120)	1976	No faults

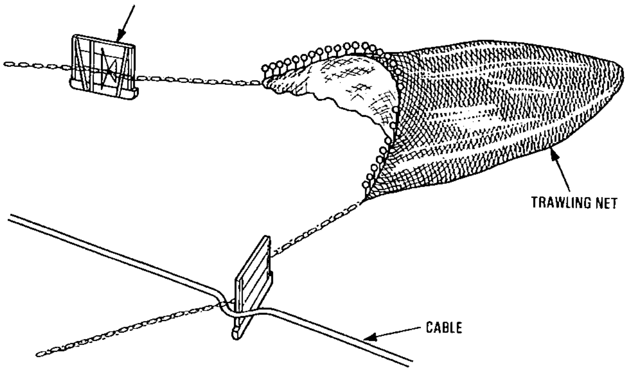


FIG. 3—The otterboard method of sea-bottom trawling

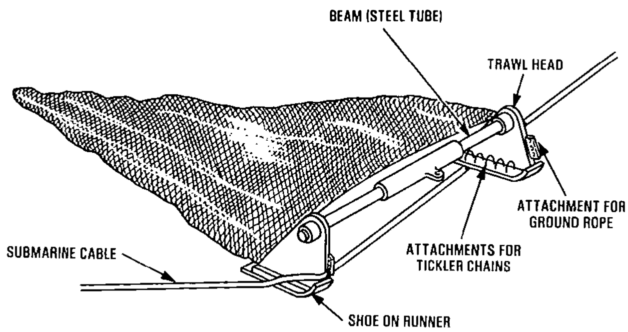


FIG. 4—The beam-trawl method of sea-bottom trawling

pair of shoes or runners, connected by a steel tube or beam. Positioned centrally on the beam is the main towing point. A conical catch net is fixed at the top of its mouth to the beam and shoes. The bottom of the mouth is weighted to maintain contact with the seabed and hold the mouth open. Chains are usually rigged across the mouth of the net to disturb the seabed and thus raise any fish into the approaching net. The beam and shoes, excluding net, often weigh in excess of 4 t and, during trawling, can achieve a depth of penetration approaching that of the otterboard trawl.

A decision on depth of burial must be based on the following considerations:

(*a*) the seabed penetration expected from the range of equipments considered likely to inflict damage;
(*b*) the frequency of cable failures resulting from the various equipments;
(*c*) the types of seabed in which burial is required;
(*d*) the depth of water in which burial equipment is to function; and
(*e*) the practicalities of achieving an economic burial and recovery facility for the depth selected.

Ideally, burial should protect against all damage. This would require a depth of burial of several metres to cope with the anchors of modern bulk carriers, which can weigh many tonnes, and are designed specifically for penetration and engaging the seabed. However, the probability of failure from anchor damage is low compared with that from fishing. Furthermore, it is thought to be highly impractical to achieve an economic system for burial depths in excess of 1 m. As a consequence, BT has decided on a nominal 60 cm for depth of burial, and has restricted burial to areas where fishing is likely to occur. Burial in rock is, therefore, specifically excluded at this time.

Fig. 5 illustrates the range of depths achievable by trawls and anchors; this demonstrates that burial to 60 cm will adequately protect against all trawling activity, and will also afford some protection against anchor damage. If fully implemented, this could result in a 75% reduction in cable faults resulting from external influences.

METHODS OF CABLE BURIAL

Over the years, techniques have been developed for the burial of submarine cables. For the most part, these have consisted of established land techniques, suitably adapted to meet the more complex demands of submarine operation. Methods of cable burial using these techniques can be split broadly into 2 groups:

(*a*) *Buried as laid* This method applies to new systems under construction and consists of the simultaneous laying and burying of cable and repeaters, now generally achieved by ploughing.

(*b*) *Post-lay burial* This method involves the burial of cable that has previously been laid on the seabed. It is usually applicable to maintenance of existing systems, but can also be used for burying new systems shortly after they have been laid.

Buried-as-laid Methods

Ploughing has been established as the most practicable system for the burial of submarine cable systems under construction, particularly in deeper water. Successive developments of the plough have resulted in optimisation of a system that offers a high degree of efficiency because of the ability simultaneously to lay and bury cable using a single cableship, usually assisted by a tug. A typical ploughing arrangement is outlined in Fig. 6. The plough principle has been developed by AT & T, KDD and NTT†, and the present state of the art of their 3 separate developments is summarised in Table 3.

The following aspects are common to all 3 plough systems.

(*a*) They all use simple designs; this is necessary for high reliability.
(*b*) They all provide facilities for monitoring and controlling the disposition and performance during operation. Telemetry and power supplies are provided over a composite umbilical cable, which connects the plough with services onboard the cableship.
(*c*) They all require a cableship capable of the high towing forces necessary for ploughing. This force, coupled with low burying speeds, requires large amounts of power, bow and stern thrusters or an attendant tug for ship control, and a sophisticated navigation system for accurate burial.

Post-lay Burial Methods

Early post-lay burial systems have, in the main, been based on jetting techniques (water or water/air mixtures). They are generally high-flow medium-pressure systems and range from jetting tools directed by divers, through to purpose-built jetting structures that straddle the pipe or cable and extend into the seabed to the required depth of burial. Water jets break up the seabed and the water/air mixture lifts the soil out of the trench, allowing the cable or pipe to sink to the bottom. Motive effort along the route is provided by surface tow. Generally, these systems are successful; work

† AT & T—American Telephone and Telegraph Company
KDD—Kokusai Denshin Denwa
NTT—Nippon Telephone and Telegraph Company

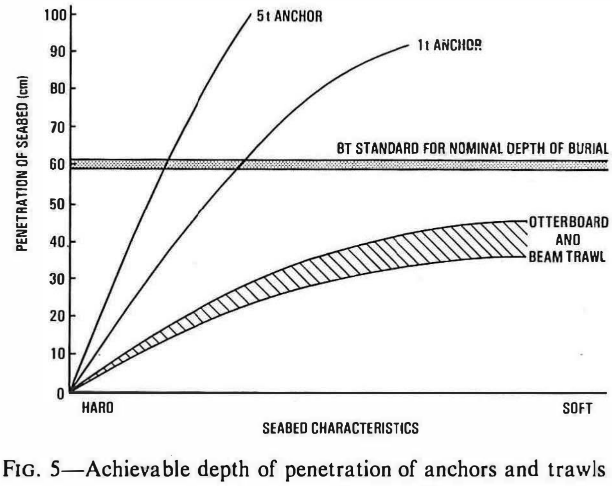


FIG. 5—Achievable depth of penetration of anchors and trawls in operation on the seabed

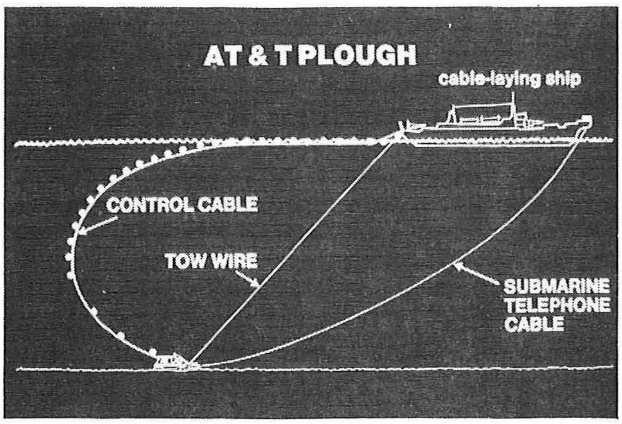


FIG. 6—Ploughing of submarine cable

TABLE 3

Summary of Operational Cable Ploughs

Burial System	Size (m)	Weight (t)		Depth of Burial (cm)	Trench Width (cm)	Maximum Working Water Depth (m)	Rate of Burial knots (km/h)	Towing Tension (t)
		Air	Water					
AT & T Seaplow IV	Length: 9·75 Width: 3·05 Height: 3·05	25·5	20	Variable to 60	40	900	0·5–2·0 (0·95–3·7)	Typically 18·3–27·5
KDD KS–1 7 bladed multistage plough	Length: 7·06 Width: 2·2 Height: 1·44	6·8	5·3	Variable to 70	30	200	0·5–2·75 (0·95–5)	Typically 10·2–25·5
NTT MK III Burying Machine	Length: 8·2 Width: 4·1 Height: 3·5	15·5	12·2	Variable to 150		100	0·5–2·75 (0·95–5)	Typically 12·2–18·3

is, however, limited to shallow water because of the fluid resistance of hoses used for delivery of air and water from pumps, which are located on the surface barge or support ship. They are also current and depth limited because of the need to have divers in attendance to supervise the operation.

In the telecommunications industry, the limitations of shallow-water working were overcome by the attachment of a jetting system to submersible vehicles. In 1971, AT & T investigated the possibility of jetting from the manned submersible *Pisces,* owned and operated by Vickers Oceanics Ltd. In 1974, the company progressed to the development of the remotely-operated vehicle (ROV) called *SCARAB*—Submersible Craft Assisting Repair and Burial. As the name suggests, *SCARAB* is a maintenance tool, and is intended primarily to assist with recovery of buried cable for repair and subsequent reburial of the repaired section. Although *SCARAB* is capable of performing at depths down to 1000 fathoms (1·85 km), it has not been developed for burial of long lengths of cable. Fig. 7 is an illustration of *SCARAB* working from a support ship; this is typical of an ROV operation, in which a seabottom vehicle is powered and controlled over an umbilical cable connecting it to a control interface onboard a support ship.

Comparison of Burial Methods

The relative benefits of the 2 methods of burial (that is, bury as laid using ploughs, and post-lay burial using ROVs) can be summarised as follows.

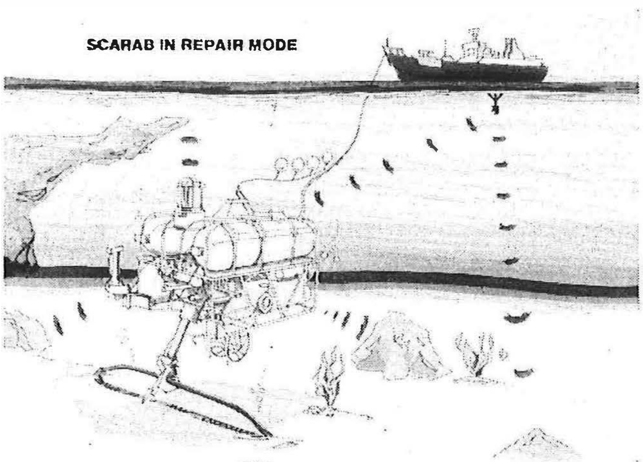


FIG. 7—*SCARAB* in operation

(*a*) Ploughs have a high burial rate of typically 15 nautical miles (28 km) per day, compared with that of an ROV which is typically 2 nautical miles (4 km) per day.

(*b*) The plough offers considerable efficiency of operation by the simultaneous laying and burying of cable, although the process is much slower than the normal seabed laying speed of up to 6 knots (11 km/h).

(*c*) When ploughing, a simultaneous laying and burying operation ensures that, the cable is protected as soon as it is laid. This is not the case with ROV systems where the cable is at risk in the interval between lay and burial. Because of the relatively slow rate of progress with ROVs, this may be an unacceptably long period of risk.

(*d*) Ploughs cannot bury cables previously laid on the seabed, nor assist with repair and re-burial, this being a prime activity for a post-lay burial ROV.

(*e*) Ploughing becomes difficult in shallow water, and in locations where other cables and pipelines cross the route of cable to be buried. Crossings of existing plant inevitably result in unburied sections. An ROV is particularly suited to this activity because of its flexibility of operation. An ROV's progress is not tied to the progress of a cable laying ship; consequently; it can be stopped and re-directed as necessary.

(*f*) Ploughs require a high towing force and are difficult to handle during operations. This restricts their use to a limited number of cableships.

Clearly, there are benefits and limitations associated with both methods of burial, and neither method can provide the full range of performance required. However, taken together, they complement each other to provide a total burial capability for the construction and maintenance of submarine cable systems.

BT's PROPOSALS FOR CABLE BURIAL

BT proposes to provide optimum protection for future systems by means of cable burial, and is currently considering undertaking retrospective burial of existing high-capacity systems where the fault history is proving less than acceptable. To achieve this, a plough facility is preferred for the installation of new systems, and an ROV facility, with post-lay burial capability, for maintenance generally and for the burial of existing systems. The ROV facility may also be used for installing new systems, provided that the risk of damage in the interval between lay and burial is acceptable.

As a plough facility is considered primarily the responsibility of system contractors, in the UK, it was left to STC to acquire such a facility. STC has secured access to the

AT & T Mark V Seaplow, operating from suitably equipped ships. As owners and operators of a cable laying ship, BTI is presently evaluating a low towing and residual tension plough suitable for operating from BTI's cableship *Alert*.

For burial and maintenance of existing systems, BT now has interests in 2 unmanned submersibles of the ROV type; that is, *SCARAB* and BTI *Seadog*. BT has a 23% share in *SCARAB* in a cable owner consortium, and total ownership of BTI *Seadog*. *SCARAB* will be available primarily for maintenance of Atlantic cables, particularly in the deeper sections down to 1000 fathoms (1·85 km). BTI *Seadog* will be used to bury and repair existing high-capacity European systems. Additionally, it will be available for work on certain Continental Shelf sections of Atlantic systems, and some work of opportunity to industry other than Telecommunications. A more detailed description of BTI *Seadog* is given below.

BTI *SEADOG*—BT's SUBMERSIBLE VEHICLE FOR CABLE BURIAL AND MAINTENANCE OPERATIONS

BTI *Seadog* has been developed jointly by BTI and Slingsby Engineering Ltd. UK, to locate and bury previously laid cable to a depth of up to 1 m, and to assist with inspection, recovery and reburial of cables during maintenance operations. BTI *Seadog* is designed for work in both free-swimming and seabottom-crawling modes, in water depths of 2–150 fathoms (4–300 m) and currents of up to 3 knots (1·53 m/s); it is therefore capable of fulfilling a vital role in the protection of submarine systems.

The equipment consists of a submersible vehicle which is connected to a support ship by means of a composite power and telemetry umbilical cable. The umbilical cable feeds into an operations control cabin, located onboard the support ship, and adjacent to a specially designed handling system capable of deploying the vehicle in conditions up to sea state 5.

The general arrangement of BTI *Seadog* is shown in Fig. 8. The vehicle consists of a glass-reinforced-plastic chassis, on which are mounted the various subsystems, buoyancy and trim, thrusters, tracks, trenching system, manipulator, video and cable detection systems. All the mechanical functions are powered by hydraulics and controlled electrically. Plastics and anodised aluminium have been used extensively to keep the weight of the vehicle to a maximum of 15 t, within a dimensional frame of 7·6 m long by 4·7 m wide by 3·4 m high.

Buoyancy and Trim

Buoyancy and trim are adjusted by pumping seawater into and between trim and buoyancy tanks, contained within 2 large pressure vessels running parallel with the forward–aft axis of the vehicle. A range of buoyancy of +400 kg to −2000 kg allows the vehicle to float during deployment, and to provide a stable working vehicle of 2 t on the seabed. The trim achievable is ± 5·5° in pitch and ± 8·0° in roll.

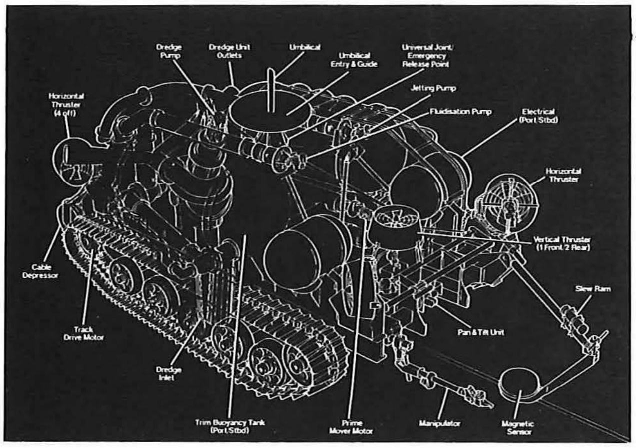


FIG. 8—General arrangement of BTI *Seadog* Mk I

Propulsion

Propulsion is by horizontal and vertical thrusters in the free-swimming mode and track drive in the seabed-crawling mode.

There are four 24 in (610 mm) ducted propellers mounted at 45° to the forward–aft axis, which are driven by variable-displacement hydraulic motors having a thrust of 645 kg. Overall, this enables the vehicle to stem a current of up to 3 knots (1·53 m/s). Control of the thrusters is by single joystick, providing horizontal plane translation and yaw (heading) control. Automatic heading can also be achieved by closed-loop control, the error signal being derived from the magnetic compass.

Vertical thrusters consist of one 24 in (610 mm) ducted propeller mounted forward and two 15 in (380 mm) ducted propellers mounted aft, driven by variable-displacement hydraulic motors and having a total thrust of 430 kg. Separate levers are provided for control of vertical, forward and aft thrusters. Automatic depth adjustment can be achieved by closed-loop control, the error signal being derived from the depth pressure transducer.

The track units are powered by 7·5 kW (10 hp) hydraulic motors, mounted in the drive sprockets of the 2 tracks. Independent servo valve control provides variable-speed forward and reverse motion, and differential steering. A total track drive force of 1819 kg is available, subject to seabed conditions. Auto tracking can be achieved by closed-loop control, the error signal being derived from the cable-following system.

Trenching System

The trenching system is operated with the vehicle in the seabottom-crawling mode; it consists of a suction dredge pump, which is capable of pumping slurry at 12 m^3/min, and is powered by a variable-displacement hydraulic motor. A tubular inlet pipe is attached beneath the pump and this can be directed to the exact area of material pick up. The inlet pipe is pivoted and extendable, so that a variable trench depth can be achieved; when not in use, it can be raised and stowed within the main body of the vehicle.

A manifold of fluidisation jets aids the production of slurry ahead of the pick-up tube. An array of controllable water jets is provided: high-flow, low-pressure (6·9 m^3/min, 400 kPa (55 lbf/in^2)) for fluidising sand; and high-pressure, low-flow (1550 kPa (225 lbf/in^2), 1·4 m^3/min) for dislodging and cutting clay.

Sensors are provided to monitor dredge deployment rotation and extension, and longitudinal and lateral forces during burial operations.

Manipulator

A general-purpose manipulator is provided on the front of the vehicle. This is used for placing acoustic markers, and assisting with cable cutting and attachment of cable grippers during recovery and repair operations. The manipulator is slaved to a master arm located at the control console, and has 5 degrees of freedom with position feedback plus grip and jaw rotation. It can cope with a maximum load of 90 kg in any direction.

Video Systems

Three video cameras are available for general surveillance during operations; these are augmented by a 35 mm stills camera for photographic records.

Low-light SIT cameras, fitted with 6·5 mm f 1·8 water-corrected standard lens, having a viewing angle of 110° with fixed focus between 150 mm and infinity, are mounted forward and aft of the vehicle on pan and tilt units (pan ±130°, tilt +45° to −60°). A further low-light high-definition camera, used during manipulator operations, is mounted on the manipulator arm. It is fitted with a 12·5 mm water-corrected lens and automatic aperture control, and has a viewing angle of 60° with remote focus control.

The 35 mm stills camera is mounted on the forward pan and tilt unit, adjacent to the video camera. It is fitted with a Nikon-Nikkor 35 mm f2·8 lens, with a synchronised shutter speed of 1/60 s.

Lighting is by 9 individually selectable 500 V A tungsten iodide lamps and an 80 J Xenon flash unit.

Cable Sensing

Cable location and tracking are achieved primarily by an active magnetic sensing system; this relies on the ferromagnetic content of the cable, and its influence on the permeability linking transmit and sense coils in the tracking system. These coils are contained in a head located on a trailing arm, which is stowed within the vehicle when not in use. Initial positioning of the head is manually controlled from the control console. Once the head is over the cable, automatic working is selected and closed-loop control of the arm is initiated, using the cable-follower *left/right* signal to maintain the coils over the cable. This *left/right* signal is also displayed to the operator, and is used for automatic steering the vehicle during cable-burial operations.

An alternative cable detection system relies on the sensing of the magnetic field radiated from a submarine cable when a 25 Hz current is injected at the shore station. The sensing heads for this system are rigidly mounted on the vehicle mainframe so that they are equidistant from the centre line of the vehicle. The system provides cable left/right and depth-of-burial information.

Umbilical Cable

The umbilical cable provides a means of transmitting power to the vehicle from the control cabin, and also provides data and video links for remote control. The end terminations are designed as plug-and-socket connections. The cable comprises 3 distinct conductor groups:

(*a*) Six 35 mm² annealed copper conductors provide the 3-phase 1000 V supply to the two 90 kW motors in the hydraulic power pack.

(*b*) Three 2·5 mm² annealed copper conductors provide the 3-phase 1000 V supply for vehicle instrumentation.

(*c*) Four individually sheathed and screened quads with conductor of 0·35 mm² annealed copper. Quad 1 is used for the data link, quad 2 for video and quad 3 for acoustic systems. Quad 4 is spare.

The cable core is sheathed in polyethylene and overlaid with 2 layers of contrahelically-wound 14 SWG galvanised steel wires. The armouring is covered in a Terylene braid and over-sheathed in polyurethane. The cable has a breaking load of 45 t, a minimum bending radius of 1 m, a diameter of 68·4 mm and weighs 8 kg/m in air.

Data Link

The data link is based on the Motorola 6800 microprocessor. Data passes from the surface to the vehicle and from the vehicle to the surface under the control of 2 microprocessors, which maintain an orderly flow of information and increase noise immunity. Data is transmitted by means of advanced data link control procedure, using blocks of data with overall block parity checking. Data causes command action only after the block check is correct. In the event of serious data error, a data-link-failure alarm is enabled and frame failure count is provided.

Navigation and Position Systems

The vehicle is fitted with magnetic compass and depth, attitude, pitch and roll sensors, and these variables are displayed at the control console.

A subsea acoustic navigation system provides the operator's control console and ship's bridge with the position of BTI *Seadog* in relation to the support ship. The same system is used to trigger emergency recovery systems acoustically through the sea. Further acoustic systems are provided for obstacle avoidance, trench profiling and acoustic marker location.

PROGRAMME

BTI *Seadog* successfully concluded the first stage of trials in Loch Linnhe in March 1982. Further trials, working from BTI's *CS Monarch*, are scheduled; there remains a considerable task to develop and optimise the system, and establish operating practices before BTI *Seadog* is fully operational in mid-1983.

CONCLUSIONS

The inevitable expansion of global communications will increase the demand for submarine cable systems of even greater circuit capacity in the future. BT's policy is to ensure that the best possible protection is provided against environmental hazard, consistent with economy. To this end, cable burial equipment and techniques are being developed. In the short term, BTI *Seadog* will be operational in 1983, and a BT plough could be developed for service in 1987. Attention is also being given to the development of route survey and laying methods, to provide greater accuracy in terms of cable position and slack. Precise placement on the seabed will facilitate effective burial and swift reliable recovery for maintenance.

World demand on the marine environment for protein, mineral and energy resources will also influence the security of submarine cable systems. For example, there are already indications of increasing fishing activity at depths in excess of 500 fathoms (926 m), using trawlers of over 1490 kW (2000 hp). Protection methods must be continuously developed to anticipate and combat this and future challenges. Because of the complexities and high cost of working in a marine environment, success will be achieved only by a continuing high level of scientific and technological effort. Existing international co-operation and interchange of information must be sustained, indeed enhanced, to ensure that submarine systems continue to provide economically a high-quality service with a minimum of interruption.

ACKNOWLEDGEMENT

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KiloStream—A Digital Bearer for the Information Age

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U.D.C. 621.394.4:681.327.8

The British Telecom (BT) KiloStream service has been operational since January 1983. This service, providing digital leased-line facilities, brings all the advantages of digital transmission to the customer with data transmission needs. This article outlines briefly the service and describes the equipment, designed by Marconi Communication Systems Ltd., which BT is using to provide KiloStream.

INTRODUCTION

The British Telecom (BT) KiloStream service offers up to 64 kbits/s digital leased-line facilities, particularly for use by the business community. The equipment for this service has been in production since September 1982, and the first customer was connected in January 1983. The aim is for approximately 200 sites in the UK to be equipped to offer KiloStream by late-1983.

KiloStream is one of the X-Stream digital services being strongly promoted by BT at the present time. Other services in the family are MegaStream, providing 2 Mbit/s and 8 Mbit/s leased-line facilities (and possibly higher bit rates in the future), SatStream, a satellite service for business use, and SwitchStream, offering packet-switched and circuit-switched services.

For many years, digital transmission equipment has been intalled in telephone networks at home and overseas, yet has not been extended to customers' premises to provide improved data services. KiloStream is the first service in the UK to offer digital leased lines to the end user, and one of the first in the world to offer coverage to a wide area of a country.

Basically, the system makes use of 64 kbit/s time-slots, and extends these out to customers' premises on standard local telephone lines using WAL2 diphase transmission.

The customer is provided with an interface equipment known as a *network terminating unit* (NTU) which offers a standard CCITT* data interface of X21*bis* (V24 or V35) or X21, and which enables user data to be transmitted duplex at 2·4, 4·8, 9·6 or 48 kbit/s with data control and supervision, or at 64 kbit/s without these facilities. The NTU encodes the data for transmission to the local telephone exchange where it is input to a 2 Mbit/s multiplexer with 31 channels of time-slot access, and the data is then conveyed across the network within a pulse-code modulation (PCM) frame structure (less time-slot 16 capability).

Leased-line routeing is achieved by time-slot interchange at cross-connection sites within the network, and at these sites synchronisation facilities are introduced in order to provide a fully synchronous service. Extensive supervisory and monitoring facilities are provided, and alarms are concentrated at cross-connection sites.

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*CCITT—International Telegraph and Telephone Consultative Committee

Although the service was initially envisaged as a purely data service, speech encoding is now available at the time-slot level (that is, 64 kbit/s A-law encoding), and lower-rate speech encoding will be introduced, enabling full integration of voice, data and text transmission to be achieved. Also provision has been made for the transmission of multi-time-slot signals (that is $n \times 64$ kbit/s).

The contract for the development and initial supply of this ambitious project was let to Marconi Communication Systems Ltd. in June 1981, and a large number of NTUs and 2 Mbit/s multiplexers, together with the synchronisation, routeing and supervisory equipment are currently on order.

The large development team involved in the initial design is now concentrating on various enhancements to the service which will be introduced over the next 2 years, such as time-slot sub-multiplexing for speech and data, and the introduction of computer-controlled time-slot-interchange equipment at cross-connection sites: This latter equipment, known as *automatic cross-connection equipment* (ACE), will replace the existing hard-wired distribution frames and associated equipment at cross-connection sites and will enable leased-line routes to be set up and monitored from network control centres. At the cross-connection sites, the number of 2 Mbit/s ports range from 8 to 432, providing a total of approximately 100 000 crosspoints at 64 kbit/s.

THE KILOSTREAM SYSTEM

The system configuration is shown in Figs. 1 and 2. The basic components of the system are: the local-line system, comprising the NTU and the line card; the 31-channel multiplex equipment; and the cross-connection equipment, including synchronisation and maintenance facilities.

The local-line system makes use of normal, unconditioned telephone pairs, taken two at a time to give a 4-wire connection, using planning rules similar to those used for the standard telephone connection. Normally, the NTU is co-sited with the data terminal equipment (DTE), and the line card and multiplex equipment are situated at the local telephone exchange. However, for organisations with a large amount of data and/or speech traffic, it may be worthwhile to site the multiples at the customer's premises.

Subscriber Interface and Signalling

CCITT Recommendation X21 is the standard for a general purpose interface for synchronous operation on public data networks, and makes use of a simple set of interchange circuits using balanced pairs (Fig. 3). This is much more robust than the V24/V28 interface and can be used over greater distances. The control interchange circuit is used to indicate the status of the transmitted information (that is,

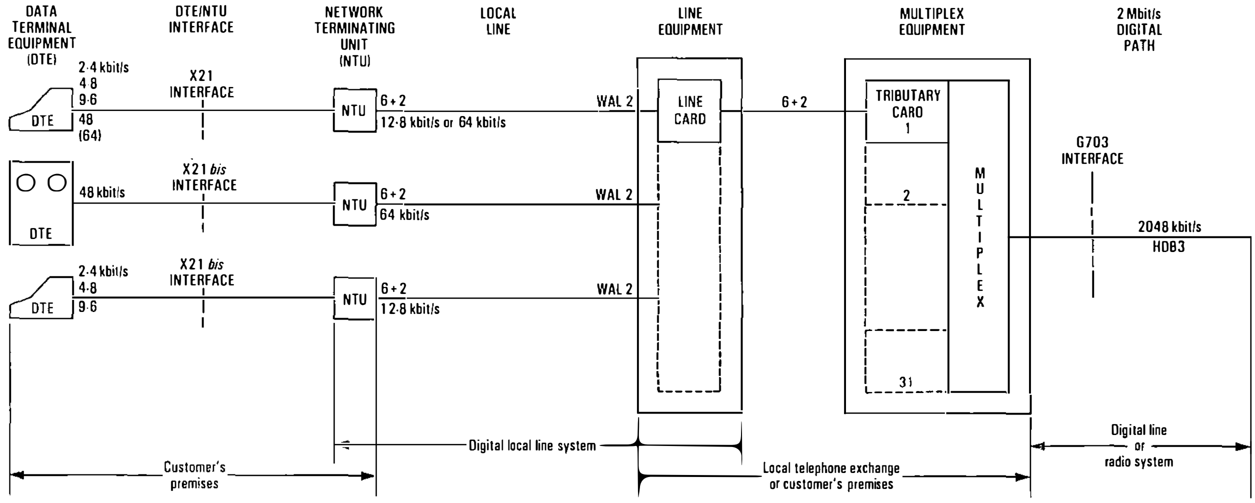

FIG. 1—Basic system configuration

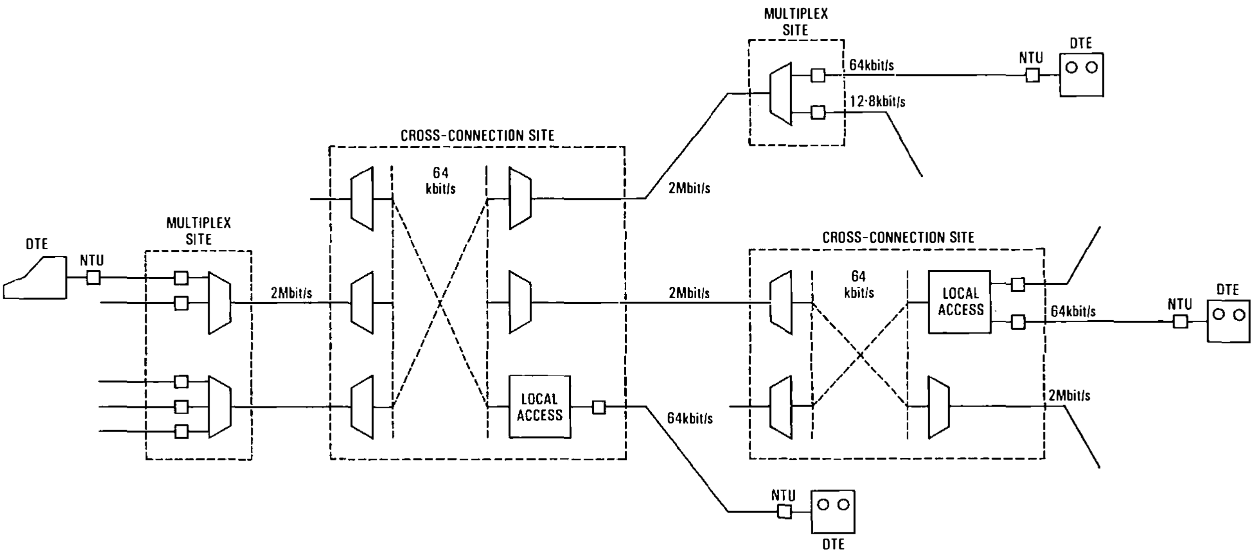

FIG. 2—Network routeing

whether the information is DATA or SIGNALLING), and this is conveyed within the status bit of the structured signal sent to line (Fig. 4). The alignment bit alternates between 1 and 0 in successive envelopes, thereby indicating the start of each 8-bit envelope. The indication interchange circuit indicates the status of the information received from line.

Recommendation X21 *bis* recognises that most of today's data terminals make use of V-series interfaces, and enables these terminals to be connected to data networks by mapping the relevant interface conditions on to a structured line signal.

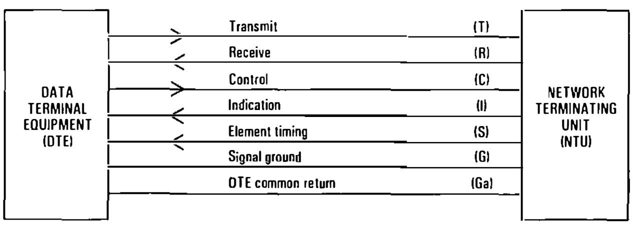

FIG. 3—CCITT Recommendation X21 interface

THE NETWORK TERMINATING UNIT

The functions performed by the NTU are control of the interface, envelope encoding and line encoding, plus the reciprocal decoding functions. The envelope encoding structures the user data into a 6+2 format to provide an associated signalling and control path, and thereby increases the data rates referred to earlier to 3·2, 6·4, 12·8 kbit/s and 64 kbit/s respectively. The user rate of 64 kbit/s does not have envelope encoding applied. The signal transmitted to line is 12·8 kbit/s for the three lowest rates, or 64 kbit/s. To accommodate the two lowest rates, the signal is reiterated (that is, repeated) to give a 12·8 kbit/s signal.

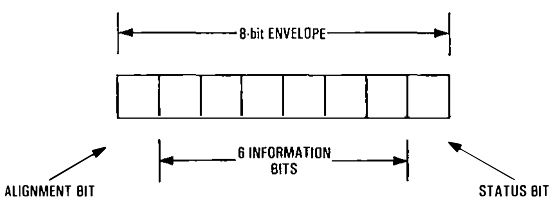

FIG. 4—Signal structured in 6+2 envelope format

The line encoding is introduced to ensure that there is no DC content in the line signal, allowing isolation of the electronic circuitry from the line, and to provide sufficient transitions in the signal to enable timing to be recovered at the far end. The particular encoding technique used is known as *WAL2*, and has the advantage that the signal energy is moved into the linear part of the amplitude/frequency characteristic of the telephone line, thereby removing the need to apply complex equalisation.

The NTU is a small, simple device, contained on a single printed-wiring board (PWB) measuring 323 mm by 201 mm, yet which is able to support transmission up to 64 kbit/s.

The board is powered by a low-voltage alternating current supply, and may either be housed in a small low-profile case (Figs.5 and 6), or rack-mounted in a 19 in shelf (Fig.7), with common AC or DC supplies. Three types of NTU are provided according to the data rate and interface used by the data terminal. The NTU with the X21 interface transmits user data at all the possible envelope encoded rates, which are plug-selectable on the board. Also, it is possible to strap out the envelope encoding function, thereby providing a user rate of 64 kbit/s. However, no independent signalling path is then available, and the interface provided is a non-standard version of X21, that is, the *control* and *indication* signals are not available on the interface. The

FIG. 5—Network terminating unit (X21*bis*)

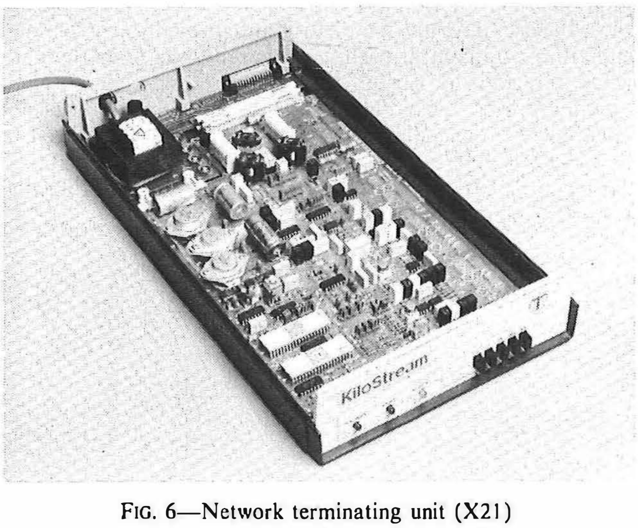

FIG. 6—Network terminating unit (X21)

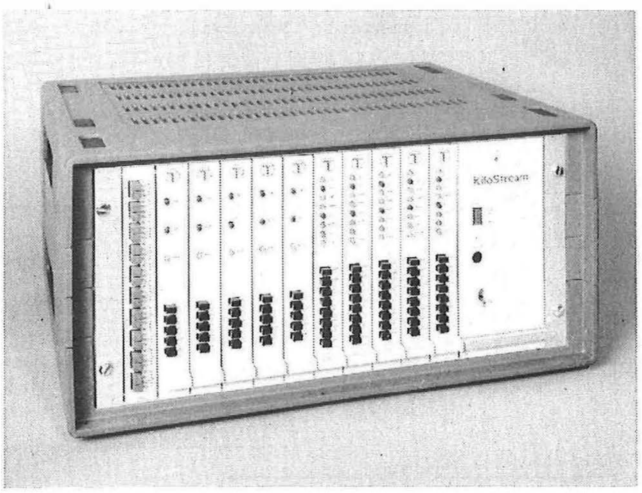

FIG. 7—Shelf-mounted NTUs in case

X21*bis* NTUs, which are designed to interface with existing data terminals using V-series interfaces, come in 2 forms, one supporting 48 kbit/s transmission from a V35 terminal, and the other supporting all the lower rates from a V24 terminal.

THE LINE EQUIPMENT

The line equipment (Fig. 8), co-sited with the multiplex equipment, performs the WAL2 encoding and decoding functions, and provides a line wetting current. Only one design is required to cover all the data rates, which are plug-selectable. The function is contained on one PWB, 222 mm ×

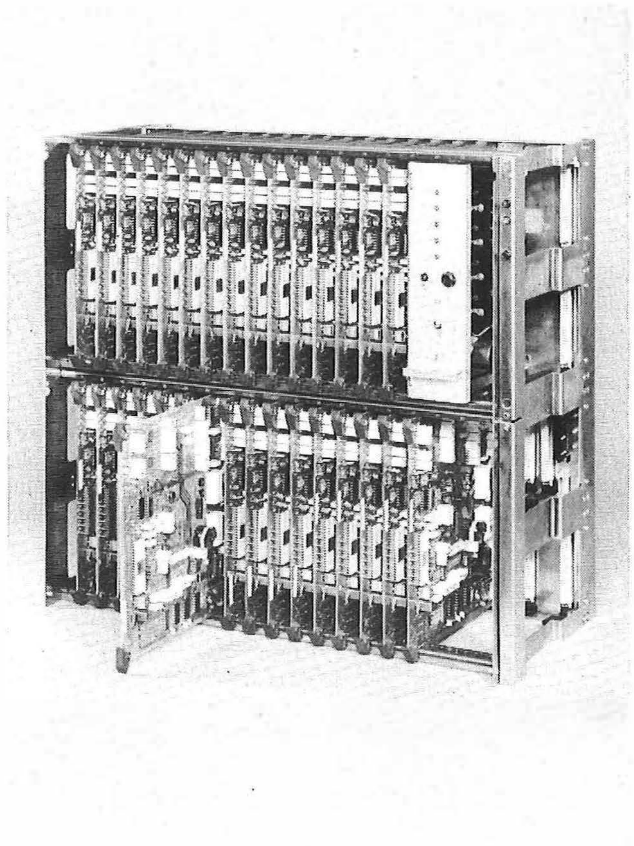

FIG. 8—Line equipment

195 mm, which is rack-mounted in accordance with the BT transmission equipment practice (TEP-1(E)) and powered from the 50 V exchange battery.

THE MULTIPLEX EQUIPMENT

The multiplex equipment contains up to 31 tributary cards which may be of a number of different types depending upon whether a particular channel is being used for speech or data, and on the type of data being presented. The multiplex structure is identical to that used in CCITT Recommendation G732 for the 30-channel PCM speech multiplex, except that time-slot 16 is made available for data transmission. The multiplex equipment (Fig. 9) is engineered in TEP-1(E) practice, and is powered from the 50 V exchange battery.

The Tributary Cards

The tributary cards are as follows:

(*a*) *The structured/unstructured data card* This tributary card takes structured traffic from the line card, reiterates it to 64 kbit/s if necessary, aligns the envelope structure with the multiplex structure, and enters the signal into the appropriate time-slot in the 2 Mbits/s multiplex frame. Unstructured traffic is handled transparently without alignment.

(*b*) *The 64 kbit/s co-directional card* This tributary card provides an interface conforming with CCITT Recommendation G703, and is used for time-slot routeing at a hard-wired cross-connection site, or for the input of data from local terminals or equipment. This co-directional interface has the merit that it provides a byte timing signal superimposed on the data, which enables byte/envelope alignment to be carried out simply when data is transferred between independent (though synchronous) frame sructures.

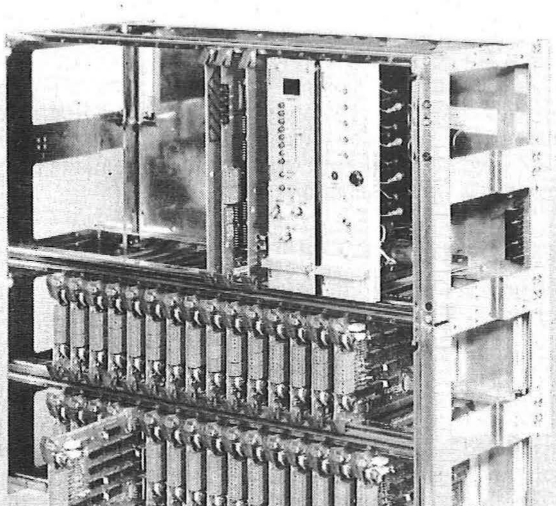

FIG. 9—2 Mbit/s multiplex equipment

(*c*) *The* n × *64 kbit/s card* This tributary card is capable of transmitting a multi-time-slot signal, where *n* lies between 2 and 30. The card interfaces with a conventional 2 Mbit/s line system which is used to convey the signal from a special NTU in the customer's premises. The multi-time-slot signal is recovered from the line system together with the accompanying time-slot 0 which is used for supervisory purposes. This signal is then inverted (that is, zeros changed for ones, and vice-versa), before the $(n+1) \times 64$ kbit/s signal is inserted into the frame structure of the primary multiplex for onward transmission across the KiloStream network. This inversion is necessary to avoid confusion with the primary time-slot 0. The signal may be inserted contiguously anywhere in the frame structure, and a number of such signals may be multiplexed together with normal time-slots. The NTU interface is an X21 style interface with *control* and *indication* signals brought out for supervisory purposes but, of course, non-compliant with X21 procedures.

(*d*) *The speech card* This tributary card employs a single channel 64 kbit/s large-scale integration (LSI) codec with combined filter. Associated signalling information can be transmitted by means of audio in-band tones (that is, within the 3 kHz speech bandwidth, and therefore encoded as speech) generated by an external signalling unit such as the widely used AC15 signalling system. Alternatively, DC signalling conditions may be transmitted via the speech tributary card, which has the ability to bit-steal on the least significant bit of the 8-bit speech sample to provide an in-slot digital signalling path (that is, within the 64 kbit/s time-slot).

Use of in-slot signalling enables individual private circuit speech channels to be routed across the KiloStream network with ease. The use of standard PCM equipment in this role requires the re-assembly of time-slot 16 signalling information at cross-connection sites, which is a complication for private circuit applications.

TIME-SLOT INTERCHANGE EQUIPMENT

Private circuit routeing is carried out by time-slot interchange at cross-connection sites strategically placed throughout the KiloStream network. Initially, at these sites 2 Mbit/s signals are demultiplexed using 31-channel multiplex equipment fitted with 64 kbit/s co-directional tributary cards, and routeing is achieved using digital distribution frames.

Also at these sites a protected synchronisation facility is provided in order to synchronise all the local multiplex equipment, and thereby all remotely connected equipment. However, this equipment will be phased out as ACE is introduced.

AUTOMATIC CROSS-CONNECTION EQUIPMENT

ACE consists of a TDM switching equipment in which the routeing of 64 kbit/s time-slots is controlled by computer from a local or remote terminal (Fig. 10). The equipment takes in 2 Mbit/s signals and demultiplexes them to individual time-slots, which it then routes to the required time-slots in the appropriate 2 Mbit/s outgoing routes. Routeing can be provided on the basis of unidirectional point-to-point circuits, both-way point-to-point circuits, unidirectional to multipoint circuits, and $n \times 64$ kbit/s circuits.

The equipment is based on a single-stage non-blocking time-space switch employing LSI cross-point arrays. Modular expansion of the number of 2 Mbit/s ports up to 128 is provided on the basis of one line card per 2 Mbit/s port, 16 line cards per line shelf, one switch card per 32-port time-slot matrix and 16 switch cards per switch shelf. The switch plane and its associated microprocessor control are duplicated, leading to high system availability.

The minimum switch configuration is a 32-port time-slot matrix, but line equipment may be sub-equipped for smaller

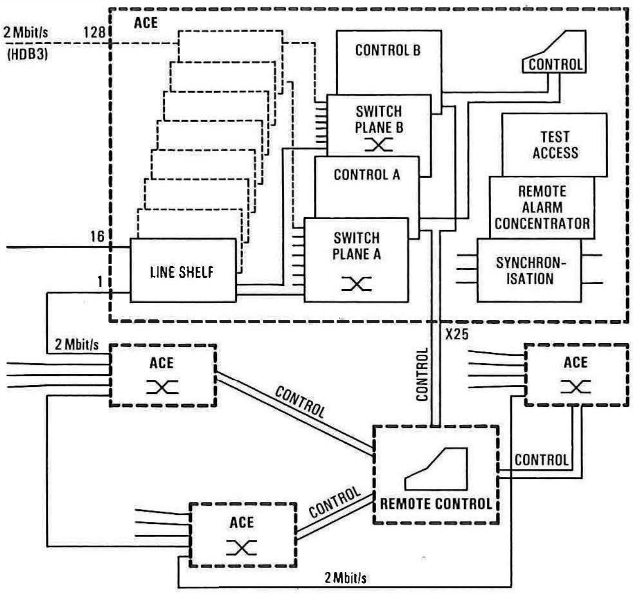

FIG. 10—Block diagram of automatic cross-connection equipment

requirements, and larger systems are provided by adding line cards and shelves, and switch cards as appropriate. For requirements above 128 ports, ACE switches may be interconnected. The equipment is designed in TEP-1(E) equipment practice.

Any number of these equipments may be interconnected and their operation co-ordinated by remote control, providing a very powerful networking capability. Also, remote alarm concentration and test access facilities are provided.

LOCAL ACCESS EQUIPMENT

The local access equipment provides facilities for interconnection of WAL2 local line systems with equipment employing 64 kbit/s co-directional interfaces. Two versions exist, a 31-channel equipment used for local access at manual cross-connection sites, and a 6-channel version that may be used for connection to such equipments as 30-channel PCM systems fitted with time-slot access. In the latter equipment, line cards and co-directional digital access cards are housed within the same TEP-1(E) shelf assembly (Fig. 11). An alarm unit is fitted to both versions which scans all tributary conditions under microprocessor control, displays the information locally, and multiplexes the information for onward transmission.

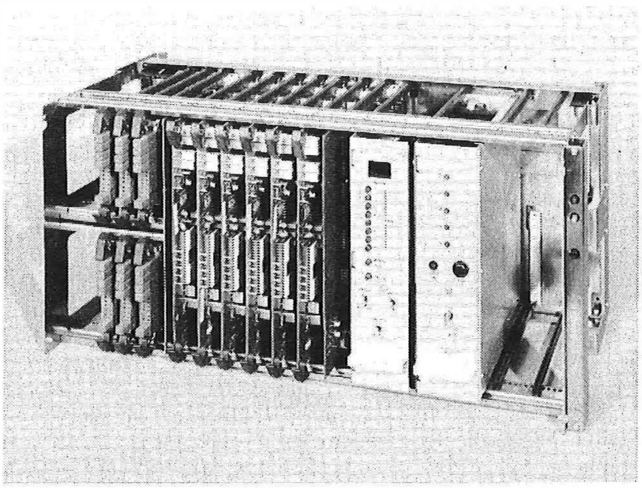

FIG. 11—6-channel local-access shelf

SUPERVISORY AND ALARM FACILITIES

The supervisory and alarm facilities are extremely comprehensive, and enable a high grade of service to be achieved. From the point of view of the data terminal operator, fault indications and local and remote looping facilities are available at the NTU. For the network controller, comprehensive status information is centrally available on all aspects of the network.

If the line signal received at the NTU is low or non-existent, or if it is impossible to achieve envelope alignment, alarm conditions are sent back to the multiplex site causing the appropriate central alarms to be raised.

To monitor the local line, a low-level DC current (5–10 mA wetting-current) is sent from the line card to the NTU and back again; if this is lost, then a line fault is indicated. This wetting-current is also used to indicate to the multiplex site whether the NTU power is switched off, by having the direction of current flows in the pairs from the NTU reversed.

At the multiplex site, the line-card monitors the level of the line signal and the presence and direction of the wetting-current, and sends appropriate indications to the alarm unit in the multiplex equipment. Similarly, the multiplex tributary card monitors for loss of envelope alignment or loss of input signal.

The alarm unit in the multiplex equipment monitors the common multiplex functions and the tributary functions. These are scanned under microprocessor control, displayed locally, and multiplexed for onward transmission on the 2 Mbit/s line system using the spare signalling capacity in time-slot 0. At the control centre(s) for the network, the status or fault conditions are fed to an alarm concentrator, which monitors the status of the network, and which is able to display the conditions existing on any multiplex equipment and tributary channel. The combination of this level of monitoring with the control capability of ACE ensures a high level of service to the customer.

In addition, test equipment is available for use at multiplex sites which can extract any time-slot from a 2 Mbit/s signal, or can be used at the tributary channel test access points.

This equipment can remotely loop NTUs and carry out various error measurements. Also, by monitoring the envelope alignment bit pattern, error measurements can be made without traffic being disrupted.

TIME-SLOT SUB-MULTIPLEXING

Although the use of reiteration of lower bit-rate services appears wasteful of capacity, the economics of the network remain very good when compared with the use of today's analogue techniques. Nevertheless, there is a case for introducing some sub-multiplexing of speech and data traffic, provided that the capabilities of an individual time-slot are not exceeded. For example a time-slot has a very large capacity to transmit slow-speed data, but it would be unreasonable to place too many separate applications on a single time-slot without back-up facilities being provided.

To meet this need, Marconi has in production or development a number of sub-multiplexing equipments for speech and data which are carefully balanced to the capabilities of the KiloStream network:

(*a*) An R111 multiplex providing up to 60 channels of Telex or slow-speed asynchronous data (0–300 bit/s), with a stand-by line capability.

(*b*) An X50 time-division multiplex providing up to 20 channels of synchronous or asynchronous data. A version of

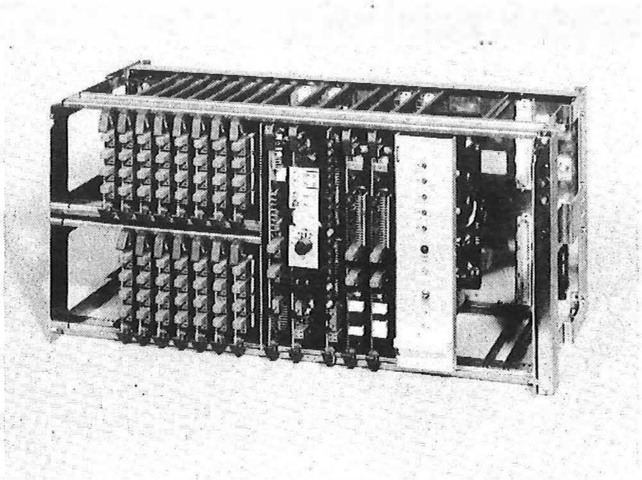

FIG. 12—R111 64 kbit/s multiplex equipment

this allows for the distribution of lower-speed data around a site on 12·8 kbit/s WAL2 line systems using expansion units.

(*c*) A 32 kbit/s speech and signalling capability, combined with a reduced number of X50 data channels.

(*d*) An 8 channel statistical multiplex combined with a 32 kbit/s speech and signalling capability, or an X50 time-division multiplex.

Apart from the R111 multiplex, which is shelf mounted in TEP-1(E) practice (Fig. 12), all the units are housed in low-profile cases in the style of the KiloStream NTU.

When today's data and speech services are integrated, it becomes apparent that speech at 64 kbit/s is particularly greedy on capacity. In the public domain, the world-wide investment in 64 kbit/s encoding, transmission and switching is so high that no fundamental change can realistically be introduced and, with the expansion of information technology in the future, it is likely we will be thankful for the capacity being built into the world telecommunication system. However, on long-distance trunk circuits, and within private networks, there is scope for introducing lower bit-rate speech, whilst accepting that quality standards must be maintained, and that connectivity to circuit-switched services should not be inhibited. This implies the use of good-quality voice coding rather than vocoding, and the ability to convert to standard 64 kbit/s PCM with relative ease.

In today's world, continuously variable slope delta (CVSD) modulation is well proven in the military field, and provides good voice quality at 32 kbit/s. In this case, standards conversion is most easily achieved through an analogue interface, but this is little different from the situation today where several conversions between analogue and digital methods are likely to be encountered on an average public switched telephone network (PSTN) routeing. Marconi is therefore making use of CVSD modulation to integrate voice and data services.

In the next few years it is likely that CCITT will make a recommendation for 32 kbit/s speech encoding based on the use of adaptive-differential PCM (ADPCM) which will enable relatively straightforward conversion to 64 kbit/s to be achieved. Also digital signal processing technology being developed today heralds the provision of good-quality speech at bit-rates below 32 kbit/s, which will enable speech and data services to be multiplexed together more effectively, possibly in an adaptive structure which takes into account the need for minimum delay on speech paths.

CONCLUSIONS

We are constantly being told that this is the dawn of the Information Age, and when one considers the research and development investment currently being made in telecommunication networks and in office automation, then there can be little doubt that the impact of this on our business lives will be considerable within the next 10 years. Coupled with this activity is a much more broadly-based understanding of computer technology, and how it may be used, which is leading to a greater expectation and demand for new services.

Today, we still think of data, speech and text services as making use of discrete terminal devices and transmission capability, but the digital implementation of the new local and wide-area networks means that no discrimination in network terms needs to be made, other than the allocation of bit rate. Many scenarios are being proposed to link intelligent, multi-purpose terminals by means of local area networks (LANs) and/or new-generation PABXs, connected in turn to digital common-carrier services. No doubt each user will implement a system unique to his particular operational needs, but a frequent requirement will be the use of digital leased-line facilities between geographically distributed sites, and this is the market addressed by BT's KiloStream and MegaStream services.

The scope for the use of KiloStream and MegaStream is immense when the buoyant data market of today, coupled with the expanding requirement to transmit digital speech and electronic mail, and the possibilities for video and audio conferencing are considered.

ACKNOWLEDGEMENTS

Acknowledgement is made to the Technical Director of Marconi Communication Systems for his permission to publish this article, and the author wishes to thank his many colleagues in Marconi and BT who have put so much effort into the creation of KiloStream.

UXD5B: A 600-Line Digital Local Telephone Exchange

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UDC 621.395.34:621.395.722:621.734

The UXD5B is a microprocessor-controlled digital-switching telephone exchange designed for worldwide applications where the exchange capacity is not expected to grow much above 600 lines. The system offers a wider range of modern facilities than its predecessor, the UXD5A. This article also describes a compact rural version of the exchange for applications where the exchange availability is less stringent than that normally specified for higher-order exchanges.

INTRODUCTION

UXD5B is the latest addition to the UXD5 range of small digital local telephone exchanges and follows the UXD5A, which is now an established system in the British Telecom (BT) network serving rural communities in Scotland. The UXD5A has already been described in earlier issues of this Journal[1].

The UXD5A system provided basic telephony facilities suited mainly to rural communities where the exchange capacity did not exceed 150 connections. In the BT network this confined its use to a modern replacement for the aging Strowger Unit Automatic Exchange (UAX) 12. The UXD5B extends the network modernisation program to cover UAX13s and 14s. Whereas most UAX12s are located in Scotland, the larger UAXs are found in most areas of the BT network, particularly in Wales and South-West England. The costs of developing this larger size UXD5 system have been kept to a minimum by interchanging many of the most recent design advances with BT's Monarch PABX thereby continuing the practice adopted for the UXD5A, which itself was based on the original PABX design.

The UXD5B is a BT development, which commenced mid-1980, with the co-operation of Plessey and the General Electric Company, whose involvement covered export-market requirements. The public-service trial of the first production exchange is now well advanced at Muckhart, near Dundee in Scotland. BT's confidence in the design has led to substantial initial supply contracts being placed with industry in advance of completion of the trial.

This article describes the main features of the UXD5B and outlines BT's program for its introduction into the network.

BACKGROUND TO THE DEVELOPMENT OF UXD5B

The dual BT/export role of the UXD5B has been paramount from the outset of the development. The product specification, formulated at the start of the development, specified a system capable of operating both in the BT network and also in telecommunications networks worldwide with the minimum of adaptive engineering. It was recognised that a wide range of modern telecommunications facilities would be required and available on an optional basis and that the system must be capable of interworking in either a wholly analogue or mixed analogue/digital environment. The concept of a flexible-design approach has, therefore, been a major consideration throughout the development.

The UXD5A was taken as the base for the new design, and the development of the UXD5B proceeded in 2 distinct stages; namely, expanding the exchange connection capacity and widening the range of facilities offered. The objective of the first stage was achieved, by the development of a 96-port line shelf. By this means, the capacity of a single cabinet containing 6 line shelves was doubled from 150 lines to 300 lines. The extended capacity required an increase in processing power, and the 8085 microprocessor used as the main control for UXD5A was replaced by the more powerful 8088 device. At the same time, the principle of a main or central processing unit (CPU) and pre-processing unit (PPU) was retained. Provision of a second 300-line cabinet and the interposition of a pulse-code modulation (PCM) interface card, specially developed for the UXD5B, between the respective control units enables the two 300-line units to function as a single 600-line exchange.

The second but parallel stage of development included the replacement of standard electromechanical subscribers' meters with an electronic bulk-billing system, provision of a wider range of maintenance and diagnostic (M and D) aids and man–machine interface (MMI) facilities. A universal signalling junction card was developed to give greater flexibility in the allocation of circuits to routes and signalling systems than had been possible with the dedicated junction units developed for the UXD5A. This new design also has the capability of interworking with signalling systems more appropriate to the export environment. Again, for the export market, the system can offer CCITT‡ R2 signalling facilities. In common with other modern systems now being introduced in the BT network, the UXD5B offers 6 of the top 8 star services (supplementary services).

The complexity of the development and the extremely short timescales set for its completion required that the work be partitioned into convenient development packages and allocated between BT and industry on a functional basis. For example, industry assumed responsibility for export facilities not required on BT applications, electronic bulk billing (call-accounting subsystem), MMI, subscribers private meters (SPM) and ringer developments. BT undertook the majority of main-system software and hardware develop-

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‡CCITT—International Telegraph and Telephone Consultative Committee

ment, junction cards and new line cards, and cabinet unit development. A new DC–DC converter was developed under contract with a firm specialising in this type of design.

UXD5B SYSTEM ORGANISATION

A system block diagram of the UXD5B is shown in Fig. 1.

Line Shelves

The combination of 2 types of line shelves and backplanes is unique to the UXD5 application. The 2 types have 32-port and 96-port capacities respectively.

The 32-port shelves accommodate 2-port and 4-port line cards providing an analogue interface to subscriber's 2-wire lines. The usual arrangement on a shelf is six 4-port cards and four 2-port cards, though 2-port cards can be fitted in the 4-port positions to provide other combinations if required. The 4-port positions accommodate mostly PBX line cards, each of which serves 4 PBX lines. These can be configured on-board to cater for either loop-calling or earth-calling PBX groups. The line card provides digital speech and signalling at 72 Kbits/s, to and from the shelf multiplex at which speech and signalling are separated onto 2·048 Mbit/s and 256 kbit/s highways respectively to the control shelf. Exceptionally, spare 4-port positions can be equipped with ordinary-subscriber's line cards of the type used on the UXD5A if required. Lines allocated to the 4-port positions would normally have calling rates well above average for this type of exchange. The 2-port positions serve coinbox (CCB) lines and junction units. The CCB line card is designed to interwork with the standard BT pay-on-answer payphones and each card serves 2 lines. The BT self-contained payphone is treated as an ordinary line with signalling from the exchange by means of the 50 Hz signals used for SPM. The junction units provide 2 junction circuits on a card and these can be arranged as either 2 incoming, 2 outgoing or 1 bothway according to the traffic requirements of a particular exchange application.

The 96-port line shelf accommodates only one type of line card, namely the 8-port line card. Each card provides connection to eight 2-wire customer's lines and a fully-equipped shelf houses 12 cards serving a total of 96 lines. Most subscriber's lines are connected to this shelf type and the originating and terminating traffic levels allow the 96 lines to be concentrated on to 32 channels to the control shelf. In this case, each line unit converts to 2·048 Mbit/s PCM, which is inserted directly into the appropriate time-slot under control of a shelf interface unit. The particular speech channel/time-slot that is used is freely allocated by the microprocessor-controlled interface unit, but it is arranged to allocate low-order numbered time-slots first. For a call terminating at a port on the shelf, the main processor will allocate a time-slot starting at the higher-ordered time-slots. Thus, there is contention only between originating and terminating calls when the 32-channel highway is nearly full. In this event, the terminating call takes priority. When all time-slots are full, an *equipment engaged* tone is returned on a terminating call and silence is transmitted to originating calls.

The actual concentration is performed by time-slot assignment codecs whose active time-slots are controlled by a microprocessor on each line card. This is instructed with which time-slot to use by the shelf-interface unit. Signalling between the concentrating-shelf interface unit and the line cards uses an 8 bit parallel bidirectional bus that is time shared between the line cards. Each line card is given a unique address determined by the wiring on the back plane. Signalling and speech are passed to and from the concentrating line shelf in the same format as for a non-concentrating 32-port shelf, enabling the same control algorithms to be used in each case.

Control Shelves

The 4 identical control shelves on the exchange (two on each 300-line unit) provide the main processing power and switching capability of the exchange. Only one control shelf on each 300-line unit of a pair of control shelves is active at any one time, the other control operates in the stand-by mode.

Each control shelf includes a change-over card, which provides the switching function necessary to allow a pair of shelves to operate in active and stand-by mode. All inputs

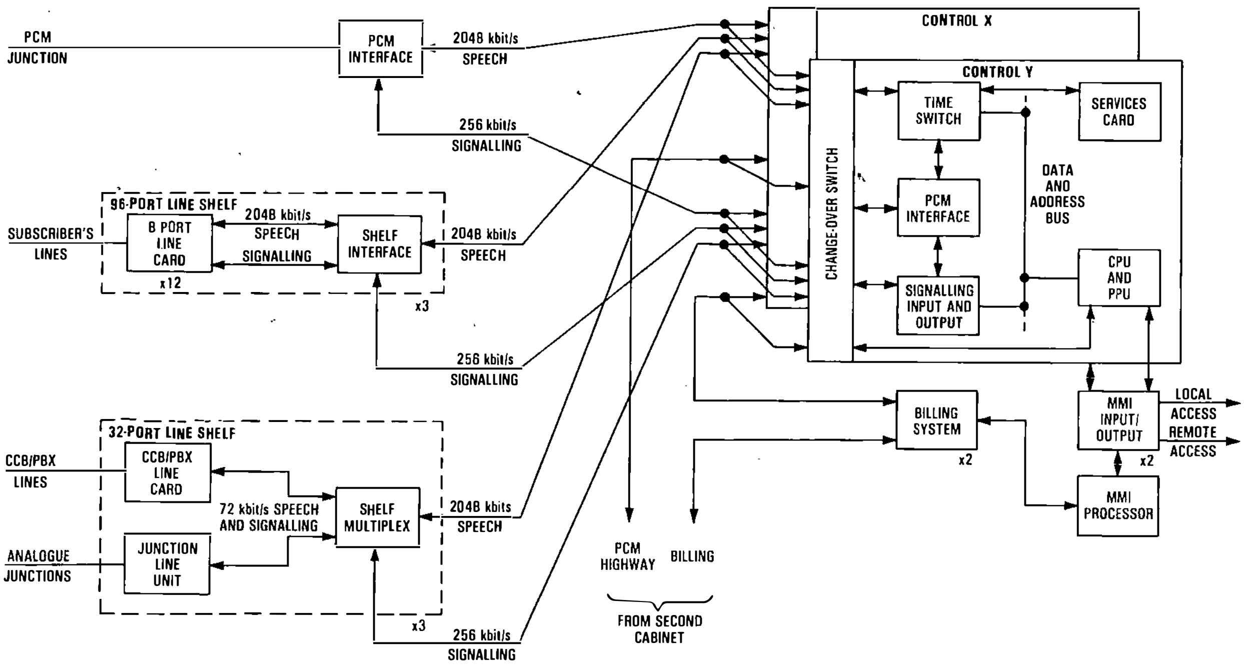

FIG. 1—Basic block diagram of UXD5B exchange system

to the control shelves are wired in parallel to both shelves, but the outputs pass through the change-over card. The cards are interlinked and the stand-by card can be activated under the control of a microprocessor on its control shelf. The change-over cards are also linked into a hardware watchdog circuit on the control-shelf processor cards. If any control-shelf microprocessor should become inactive or faulty in its behaviour, this is detected by the watchdog and the condition is signalled to the change-over card. The change-over card is designed so that it will not allow its shelf to become active if it is receiving a fault signal from any watchdog. Thus, under fault conditions, control will automatically pass to the other shelf only if all is in order. Change-over causes calls in progress to be lost. Periodic routine change-over is effected under software control and is therefore arranged to occur when no calls are in progress.

Digitally-encoded speech from the shelf interface units and shelf multiplexers is applied to a non-blocking time-switch which switches eight 2048 kbit/s 32-channel PCM highways. The timeswitch inputs also include digitally-encoded tones generated on the services card. This card provides up to 12 tones which can be either BT standard tones, CCITT standard or any combination of tones required by an administration. The tones are programmed in electrically programable read-only memory (EPROM) and a logic gate array formats the tones for a particular application under the control of the EPROM. The services card also contains 6 press-button multi-frequency (PBMF) receivers for use with press-button telephones employing multi-frequency (MF) signalling. These telephones are allocated a special port type so that the operating system automatically associates a PBMF receiver whenever MF dialling is required. The receivers decode the received digits into a form required by the main control. Where a high percentage of press-button telephones are in use, additional receivers can be equipped on cards accommodated on non-concentrating line shelves.

Several facilities on the exchange require interconnection of more than 2 speech paths; for example, 3-party service, and trunk offering. This requirement is met by using a conference bridge in which a digital summation is performed on up to 4 speech paths giving 4 outputs. Each output excludes one of the incoming speech paths such that it can be connected to a subscriber without increasing his sidetone levels by excluding his own speech. The sum is linear so that the same transmission rules apply for a multi-party call as for a 2-party call. Four conference bridges are provided on each services card.

Signalling from the shelf interface units and shelf multiplexers is applied to the signalling-in card on each control shelf. This card stores the information in a 256 byte random access memory (RAM) with each byte containing the current signalling information from a port. The processors scan the store for this information. The outgoing signalling is taken from the signalling-out card, which is another 256 byte RAM store, that can be written to by the processor. As the address of each byte corresponds to a port number on the exchange, the microprocessors can readily read and write to any port in any sequence.

The exchange continuously monitors the performance of the speech and signalling paths by performing a loop-round test. To test the speech path, a tone is switched to an IDLE line and, as the telephone is ON-HOOK, the 2-wire/4-wire hybrid balance circuit on the line card is mismatched sufficiently to allow a proportion of the tone to be reflected back through the system. A circuit on the services card detects the reflected tone and, by switching the output from the line card to the services card, the analogue-to-digital functioning of the line card is verified. A similar arrangement is used to check the signalling paths.

Each control shelf uses two 8088 microprocessors and the main program is stored in two 128 kbyte EPROM cards.

Exchange-configuration data and subscribers class-of-service (COS) information is held in battery backed RAM. As a back-up facility, the battery-backed RAM card includes an EPROM device mounted on an integral daughter board. This is automatically programmed *in situ* under MMI control.

The microprocessors are arranged as a main processor and a pre-processor. The pre-processor provides fast scanning of those ports which require it and controls the input/output with the billing processors. The main processor provides the main call-control function, and uses the majority of the program store. The processors are closely coupled and share a common bus. Both processors use the same design of board, the different functions being implemented by means of links.

Two 300-line cabinets are linked together to form a single 600-line exchange by means of a 30-channel PCM link. The link uses standard CCITT frame definitions and a common-channel signalling protocol in time-slot 16. Low-level signal processing, synchronisation and alignment are performed on-board under microprocessor control. The same basic card is also used for standard 30-channel channel-associated junction PCM systems. For the inter-cabinet application, the card is located in a control-shelf position. For interworking with a junction PCM line system, the card replaces a shelf multiplex on a non-concentrating line shelf. The 32 available ports on the shelf are allotted to 30 junction connections with ports 0 and 16 being reserved for synchronisation and signalling operations respectively.

Billing Shelf

The billing, or call-accounting subsystem, is a duplicated microprocessor-controlled system which calculates and records the charge rate for each call in progress on the exchange. The duplicated systems are linked to each control shelf by a pair of serial asynchronous links. The dialled-digit information, COS of the calling subscriber and time-of-day are passed from the main system control active control shelf to both billing planes. Each processor uses this information independently in a complex algorithm to determine the correct charging rate for the call. At the end of a call, the 2 values are compared and the final data is recorded on the subscribers 'software' meter. Any discrepancy in the recorded data is conveyed to the M and D routine for analysis and fault reporting. Billing records are stored in battery-backed CMOS RAM to maintain the integrity of the data under power-failure conditions.

The system caters for a variety of charging schemes; for example, single shot; variable time interval (VTI); and metering-over-junction, which, if required, can also be sourced to a lower-order exchange; allowing for local, national and international dialling. The billing system contains its own accurate real-time clock for local generation of charging rates. For current BT applications, bulk-billing information only is stored; however, the interfaces are designed to allow for the introduction of itemised billing. Full access to the system is available via the MMI and the data is presented in tabular form for administrative use.

Main Control Software

Most of the source code for the programs is written in CORAL using a computer-aided design (CAD) facility called *SX1*. This is a code generator which automatically produces CORAL code from program flow charts. This procedure has ensured that the code produced is easily maintainable and reduced development time. Approximately 80% of the software is written in CORAL, and the rest in 8088 assembler language. The assembler is used where either time is critical or input/output routines are being used.

The majority of the software is run by the main processor, and this is best described under the following main process headings:

Operating System

The operating system provides the link between all the other programs run on the main processor. It can start programs running either after responding to an interrupt (known as *foreground* programs) or on request from a program (known as *background* programs). Several programs perform a similar class of function and in this case they are given a similar class name as, for example, *exchange scan*, which has foreground programs that scan the ports and a background program that provides the output function to the ports. The operating system also operates general routine requests such as providing the real-time clock. It can start background programs after set delays or at specific times. It also causes the microprocessor to output a pulse every 100 ms so that the hardware watchdog can verify that it is still running.

Exchange Scan

There are 4 programs associated with exchange scanning. The main program is run in foreground and scans the complete exchange every 128 ms. Subsidiary exchange-scan programs run at 8 ms intervals and 24 ms intervals. These subsidiary programs scan ports which need a faster response to their signalling changes than the 128 ms scan can provide. Examples that require this are the detection of loop disconnect pulses from a standard telephone and the detection of digits received by the PBMF receivers. The exchange-scan background program provides the software interface to the signalling output to the ports. It also provides an interface from other programs such as call processing and M and D to the method of scanning the signalling input provided by the foreground exchange-scan programs.

Call Processing

Call processing is the program that controls the main functions of the exchange. It is a background program and acts in response to a request from other programs. It responds mainly to exchange-scan programs as its main purpose is to interpret the changes in telephonic functions reported to it and to decide what action the exchange should take.

Inter-Shelf Link

Three programs are associated with controlling the serial link between the 2 control shelves on the same 300-line rack. As for exchange scan, a background program acts as the interface to other programs and controls the output across the link, and 2 foreground programs control the reception of data from the other shelf. At present, the link is used only to communicate changes in the exchange configuration and changes in the fault status from one control to the other.

Billing

Billing also has 3 programs used to communicate between call processing and the billing processors over the serial links from the pre-processor. The programs are for a similar purpose to that described above and comprise one background program and 2 foreground programs.

Maintenance and Diagnostics

This group of programs control the automatic testing and fault reporting features of the exchange. The background program is started by the operating system every 15 s when it starts a test on one card on the exchange. As it goes through a testing schedule automatically, the complete exchange is tested every few hours. A control shelf that is in the NON-ACTIVE state cannot test line cards, but it can perform tests on its own cards, and sufficient spare processing power is available to perform more extensive tests on areas such as the RAM. A fault found on the non-active shelf is reported to the active shelf via the inter-shelf link programs so that the necessary alarm indication action can be taken. A foreground M and D program runs every 128 ms to provide validation of time-critical events.

The background program can also be started under request from other programs so that tests can be run independently of the routine 15 second test and so that it can decide what action to take on error conditions being reported by other programs.

Man–Machine Language

This is a background program that provides the control and decides the action to take in response to commands from the administration's terminal that have been passed on to that control shelf by the MMI processor.

List

The 3 programs associated with the interface to the man–machine processor are all referred to as *list* programs. They control the serial link to the MMI processor and have a background program and 2 foreground programs.

Pre-processor Software

The pre-processor has a small operating system that schedules foreground programs. The programs that run on the pre-processor are the 2 fast exchange-scan programs running at 8 and 24 ms and the fast 8 ms billing program. The firmware for these programs is contained on-board the pre-processor so as to minimise the activity of the pre-processor on the main-control-shelf microprocessor bus.

Database Handler

The function of this process is to carry out maintenance tasks on the exchange configuration database both during initialisation and during the operational life of the exchange.

PHYSICAL REALISATION OF UXD5B

The UXD5B system consists of 3 cabinet units, 2 A-units holding the line cards and central processing shelves and a B-unit holding ancilliary equipment such as the billing system, MMI processor, SPM equipment, alarm display and spare shelf positions for exchange-specific equipment. The overall dimensions of a 3-cabinet exchange are 1680 mm × 600 mm × 2080 mm. Up to about 300-line capacity, a single A-cabinet provides the necessary line equipment accommodation which, together with the B-cabinet, gives dimensions of 1120 mm × 600 mm × 2080 mm. A front view of a 3-cabinet unit is given in Fig. 2.

A-Cabinet Equipment

The A-cabinet (the outer cabinets in Fig. 2) provides accommodation for 9 equipment shelves given positional designations A–J, reading upwards. The power shelf is located at the bottom (shelf position A) and this houses 3 DC–DC converters serving the 6 line shelves above. Two ringing units, operating in main and stand-by mode, are also equipped on the power shelf. The 6 line shelves are alternate 96-port and 32-port types. The 2 control shelves serving this unit occupy shelf positions G and H. The equipment cards on both types of line shelf are interconnected by means of printed-wiring backplanes. These backplanes contain connectors for terminating the plug-ended cabling to the MDF. The backplane used on the control shelf is a wired type where the wiring is automatically wrapped during production. The 2 A-cabinets used in a 600-line exchange have identical equipment arrangements.

B-Cabinet Equipment

The B-cabinet provides accommodation for the exchange ancilliary equipment. Referring to the middle cabinet shown

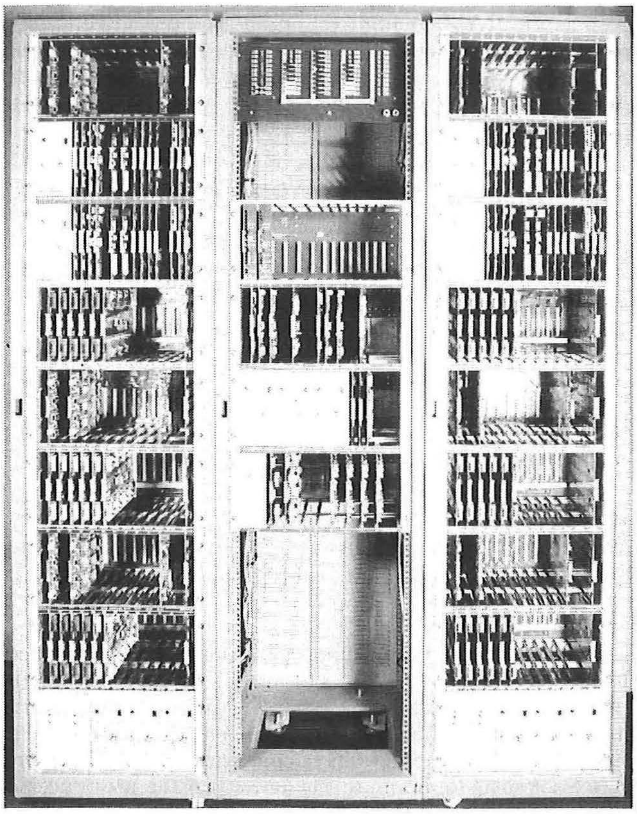

FIG. 2—Front view of UXD5B equipment cabinets

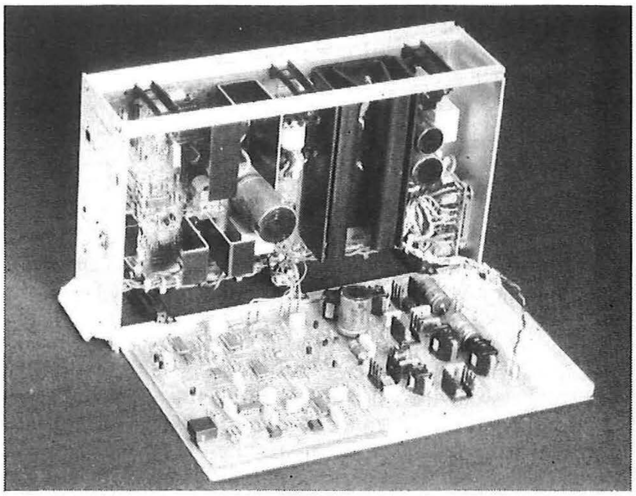

FIG. 3—DC–DC converter

TABLE 1
Typical Power Consumption

Traffic Loading (Erlangs)	Power Consumption (W)
Idle	1400
40	1900
64	2200

in Fig. 2 and reading from bottom to top, the equipped shelf positions are: SPM, MMI/power, billing, miscellaneous, fuse panel. The spare shelf positions are available for optional facilities such as remote line testing, call logger or for use as additional miscellaneous or SPM equipment positions. A visual alarm display unit occupies 2 card positions on the miscellaneous shelf. This shelf is also designed to house a range of exchange-specific equipment and, to achieve maximum flexibility, each card position on the backplane is fitted with a 64-way edge connector for wiring on and off shelf connections.

Unlike the earlier UXD5A, the main distribution frame (MDF) is not included in the B-cabinet. For BT applications a standard cable length of 15 m has been adopted for cabling between the A-cabinet line shelves and a separately sited MDF. Line shelf equipment is provided with secondary surge voltage protection on-board. Primary protection, either in the form of gas discharge tubes or 3-terminal solid-state devices, is required at the MDF Line side. An intermediate distribution frame (IDF) is not required since exchange number–directory number (EN–DN) translation is performed by the exchange software and, under normal traffic conditions and line-card disposition, the exchange is not sensitive to the distribution of traffic load between individual line units or shelves. Line cable pairs are therefore jumpered from the line side of the MDF directly to the exchange side where terminations are arranged in EN order.

Power Supplies

The equipment is powered from a conventional −50 V DC exchange battery supply. All other voltages required are derived by using specially designed efficient DC–DC converters. Details of the construction of the converter can be seen in Fig. 3. Each converter provides up to 150 W of output power made up of 102 W at +5 V, 24 W at +12 V and 24 W at −12 V. The outputs are protected against input voltage transients. Thirteen converters are distributed throughout the system to provide the required exchange availability.

On the A-cabinet, each control shelf is powered by a dedicated converter mounted on the shelf. Line shelves are powered on a paired basis, the pairing arrangement being one 32-port and one 96-port shelf. On the B-cabinet, each call-accounting subsystem has its own converter and these are located on the adjacent MMI/power shelf. A third converter on the MMI/power shelf supplies the miscellaneous equipment shelf and the SPM shelf.

Typical power consumption figures for a 600-line exchange under specific traffic loadings are given in Table 1.

100-LINE SINGLE-CABINET RURAL VERSION

A 100-line single-cabinet system has been developed. This system uses a single control shelf and is primarily intended for applications where the system availability achieved with duplicated controls and multiple line shelves is not a major requirement of the administration. With such an arrangement the mean-time-between-failures resulting in a total loss of service is expected to be in excess of 5 years. Fig. 4 shows the equipment cabinet arrangement.

The reduced-height cabinet has provision for 7 shelves of standard height. The power shelf occupies the bottom shelf position and the order of shelves above this reading upwards is: MMI, call accounting, 32-port line shelf, 96-port line shelf, control shelf and miscellaneous/SPM shelf. A fuse panel is mounted to the rear of the power shelf and an insulation-displacement type MDF is located at the rear of the line shelves. In this arrangement, the duplicated call-accounting subsystem has been retained to avoid the need for a special design for this application.

Each line shelf is separately powered from a DC–DC converter mounted on the power shelf. The power shelf also includes a main and stand-by ringer unit. The MMI shelf

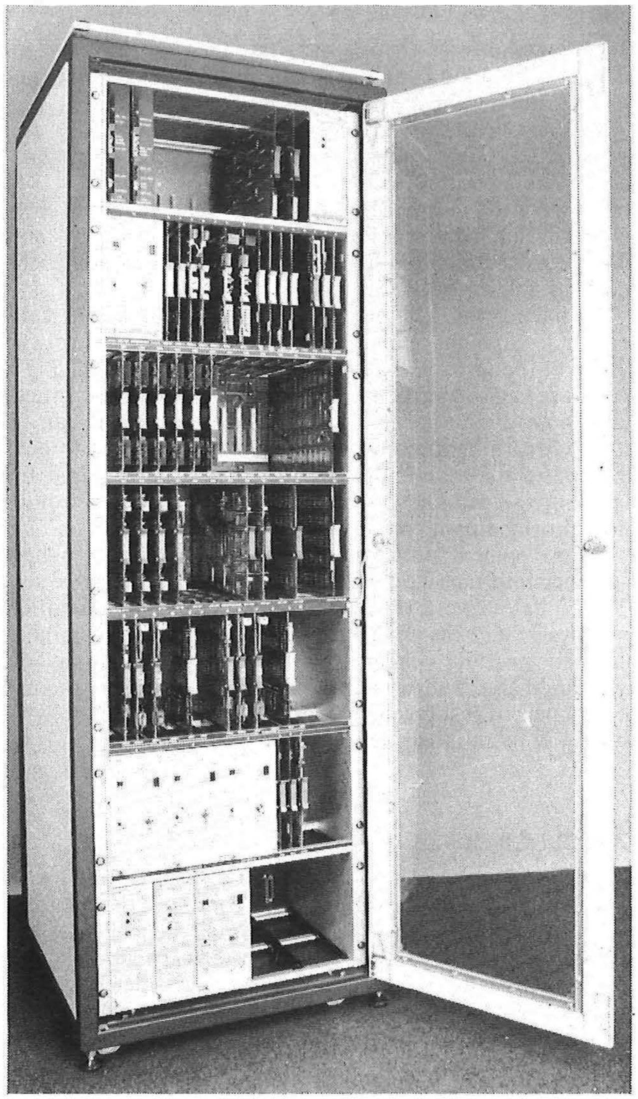

FIG. 4—Front view of 100-line single-cabinet version

accommodates the call-accounting subsystem and miscellaneous/SPM shelf converters. The control shelf includes its own dedicated converter.

UXD5B FACILITIES

It has already been mentioned that the UXD5B provides a wider range of facilities than was available on UXD5A as well as additional facilities specifically for export requirements.

Subscribers' lines have the option of 2 line-card types. The standard 8-port line card provides a nominal 25 mA constant-current feed to line. On-board gain adjustment is provided to cover lines with up to 10 dB loss. (The 4-port UXD5A long-line card is used on lines exceeding 10 dB loss.) Certain types of customer apparatus require line current in excess of 25 mA. To cater for these a card is being developed giving a nominal 40 mA line feed. This card can also provide test access to the line or exchange where remote line test equipment is fitted. Both card types provide for a limited number of shared-service subscribers.

A multiple-signalling junction card, controlled by an on-board microprocessor, is the standard analogue junction circuit for the UXD5B. It can be configured to interwork with all BT local-network analogue junction signalling systems and caters for E and M signalling for export applications. A standard message protocol is used for communication between the card and the main processor and the system therefore does not need to know the type of signalling system in use.

Where CCITT R2 signalling is required, 2 card types are provided: the receiver, and the control/sender. Four receivers are mounted on a card each handling both incoming and outgoing traffic. The control/sender card provides the control functions (the software for which resides in PROM), the MF tones and 4 senders. The control handles 4 sender/receivers, and both card types are fitted in 4-port positions on the non-concentrating line shelf.

The UXD5B provides as options several advanced customer facilities. These are provided by additional software in the call processing program and are available to a maximum of 200 subscribers on the exchange. The facilities offered and their function are described below.

Call Waiting Indication

A tone is transmitted to a busy subscriber's line to indicate that another subscriber is attempting to contact him. The other subscriber receives an announcement informing him to wait.

Repeat Last Call

This enables the last digits dialled by a subscriber to be repeated by using a short special code.

Call Diversion

The subscriber can have 3 forms of diversion which he can set up himself: divert all calls, divert on no reply (his phone will ring for a few seconds during which time he must answer or else the call will be diverted to the other number), and divert on busy (if he is already engaged on another call). In all cases, diversions can be set up only to another number on the same exchange.

3-Way Calling

While a subscriber is engaged on a call he may dial up another subscriber and put the original call into a wait state. He then has the option of speaking to both parties in a conference mode, or clearing down from one party and continue speaking to the other. For this service to have satisfactory transmission standards the conference facility is allowed only to have one party outside the exchange service area.

Call Barring (Subscriber Controlled)

The subscriber can bar certain outgoing calls made from his telephone. This is performed on recognition of the first few digits dialled and not specifically on call type.

Code Calling

A personal store is allocated to the subscriber in the exchange RAM for dialling frequently-used codes. By applying a short dialling code these numbers are recalled and passed to the switching system as though he had dialled the complete number.

Exchange Maintenance and Diagnostics

The main software of the exchange contains control for both routine self diagnostics and fault finding and operator-controlled fault finding. The aim of the M and D facilities is to detect any faults on the exchange and give their location down to plug-in unit level. On-site maintenance is confined to plug-in unit replacement. Lower levels of maintenance and repair are performed off-site.

The diagnostic software operates in 2 ways. For hardware that has no, or limited, microprocessor control, all tests are performed by the main control shelf processor. Those units that have more microprocessor control instigate their own tests and report on failure of any test to the main control shelf processor. Some units that can have catastrophic failure (for example, a fuse blowing) report errors automatically to the main processor via the howler and alarm board. Any faults found are entered into the recent fault history list which gives details relating to the type of fault, the unit that was faulty, the time the fault was found, the number of occurrences of the fault and the associated alarm category.

Another main action taken by the M and D software is the reporting of faults. If an alarm-extension junction is provided, faults deemed serious cause alarm conditions to be extended over the junction. Several categories are catered for and for BT applications these are given the following titles: *prompt alarm, deferred alarm*, and *in-station alarm*. The category of alarm determines what level of action should be taken.

Man-Machine Communication

The 4 processors on the control shelves and 2 on the billing shelf have communication links that require interface to an administration terminal. An MMI processor is provided on the MMI shelf to link one terminal to any of the above mentioned processors. To allow for multiple usage of the MMI, several input lines are provided. Up to 4 modem-interfaced lines can be provided for remote interface to the MMI processor, one local terminal, a transaction recorder and a printer so that the MMI processor gives the administration complete flexibility on the type of interface it requires.

Several levels of interface to the processor are allowed:

(*a*) *Fault status level* The administration can access the MMI processor such that a brief form of the fault record for each control shelf on the exchange can be printed out (referred to as the *active alarm list*).

(*b*) *Billing Access Level* By using different passwords, the administration can gain access to the billing information and enable a dump of the billing records to be given. At this level no access is permitted to the main processor MMI.

(*c*) *Main MMI level* By using different passwords again, the administration can gain access to the man–machine language on the main processors. By using this, full access is gained to the M and D facilities on the exchange and the exchange configuration can be altered and listed.

(*d*) *Specialist user level* This allows designers to interrogate the system for debugging etc. To avoid conflict between simultaneous users, only one user is allowed access to a particular exchange function at any one time.

Remote access to the exchange MMI is provided via modems. These can either be switched or on private wires. To provide extra security on switched connections, the log-on procedure is as follows. A special code is dialled into the exchange and the exchange recognises it as a special call type requiring MMI access. The call is cleared down and the exchange dials out on a pre-configured number and connects the modem when a satisfactory connection has been achieved. Several of these numbers can be configured, one to each MMI access number, to allow access for a number of administration sites. Full access is still not attained until the necessary logging in procedure has been followed.

FUTURE DEVELOPMENTS

In conjunction with British Industry, the UXD5B development is continuing further, mainly in the areas of customer services and administration facilities.

Advanced customer services such as call reminder and call-charge advice require a voice guidance and announcement system to ensure that the service is correctly set up and responding in the required manner. These are currently under development for BT applications. A number of systems already exist and work is currently in hand to adapt the most suitable to UXB5B.

BT have embarked on a trial program of fitting call-logging equipment in all local exchanges. In the case of the UXD5B, the intention is to produce an equipment having a hardware and software interface with the exchange identical with those of the normal billing system so that it can be fitted as an alternative on an optional basis. Some additional changes to the main system software will be required for handling the message protocol between associated equipment provided on a common basis in the network.

A development projected for the longer term is a new customer-interface card capable of providing integrated services digital network (ISDN) facilities. New administration facilities include the provision of the CCITT No. 7 common-channel signalling system and a message transmission sub-system (MTS). These will offer UXD5B customers the use of co-operative supplementary services in common with System X in an integrated digital network.

CONCLUSION

The development of the UXD5B is a joint BT and British Industry activity. In the case of BT it continues the program of rural-network modernisation, which began with the introduction of the UXD5A. The larger capacity UXD5B will be used mainly as a replacement for the older UAX13s, 14s and SAX exchanges in Scotland, Wales and South-West England. To meet this program, initial orders have been placed with industry for over 350 exchanges covering a 3 year supply period. Not only is the UXD5B suitable for integration into an eventual all digital network, the wide range of advanced facilities it can offer, together with a continuing development program, mean that it will meet the future needs of the customer for the foreseeable future with minimal change to the overall system architecture.

Much interest is being shown in the UXD5B by overseas administrations, and BT's own commitment to it should enhance the success of the product in export markets.

ACKNOWLEDGEMENT

The authors are indebted to all those colleagues involved in the project both in BT and in Industry for the help and advice given during the preparation of this article.

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British Telecom Teletrade

G. R. PRICE†

UDC 621.39:381/2

As British Telecom's (BT's) network is modernised a great deal of telecommunications equipment is being displaced which, although used, is still serviceable. BT, under the marketing name Teletrade, is selling this equipment overseas. As well as a wide range of products, Teletrade can provide a comprehensive range of back-up services, including refurbishment, installation and after-sales services. This article outlines the services offered by Teletrade and highlights one of its important range of products—containerised Strowger exchange systems. Teletrade also has a range of high-technology products; this article introduces one of them—the Teletrade City Business System.

INTRODUCTION

Britain's telephone system has always used the very best equipment, which is often replaced with more modern hardware well before its physical working life is through. Modernisation programmes throughout the British Telecom (BT) network are gaining momentum and a positive start towards establishing an integrated digital switching and transmission network has been made.

Full modernisation, which will take many years to complete, will result in a great deal of telephone equipment being made redundant. Although this equipment is by no means faulty or substandard in any way, its longer-term use is simply not consistent with BT's modernisation programme. The equipment being released from service includes Strowger exchange switching apparatus, dial-operated telephones, small private manual and automatic exchanges (PMBXs and PABXs), electromechanical teleprinters, exchange sleeve-control switchboards and many other items.

Rather than destroy this equipment, or sell it as scrap, BT's policy is to sell the equipment in overseas markets, under the marketing name of *Teletrade*.

BT obviously receives additional income from this, while the purchaser acquires good-quality proven telephone equipment at relatively low cost. Many maufacturers have made it clear that they intend to curtail the manufacture of Strowger and related products in favour of high-technology designs. This could cause problems for the many areas of the world which do not have the means to install the latest ranges.

As the supply of new Strowger exchanges and similar equipment dries up, many countries' demand could remain unsatisfied. Therefore, Teletrade, with its large stock and increasing supply of older equipment, is well placed to fill the market gap.

TELETRADE SERVICES

Depending upon the requirements of Teletrade's customers, and the expertise of local engineers, equipment can be offered in various states of refurbishment. Some may be sold 'as found', while some can be completely overhauled and sold in 'as new' condition complete with new cabinets and panels.

Recovered Strowger equipment that is refurbished in BT's factories conforms to very high standards. All worn parts are automatically replaced, so that every item sold should give good service for many years. The age of the equipment is usually less than 10 years, but the age factor is not really important because maintenance procedures in the UK and pre-sale servicing ensure that the equipment is of the highest standard.

Purchasers who have the capability to overhaul their own installed equipment may simply buy hardware, and others may require one of Teletrade's after-sales service arrangements, training or one of the warranty contracts which are offered.

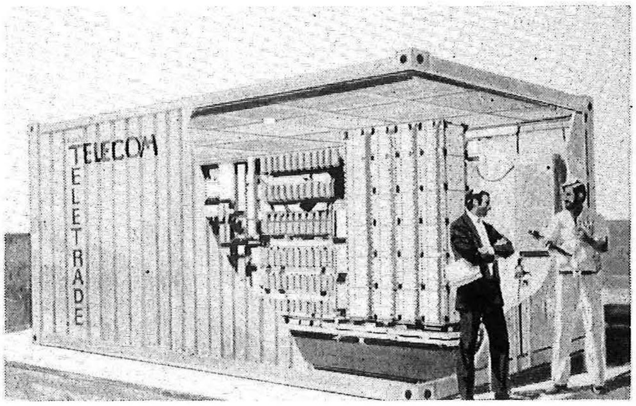
Another factor which is often part of the sales arrangements is that of financing. Many potential customers for BT's equipment are in developing countries which have budgets that cannot fully cover the costs of equipment. Their desire to develop as a nation would certainly be helped by the installation of a telephone system and all the economic and social benefits which stem from it. But they simply do not have the funds. In such cases Teletrade is able to offer attractive financial terms to enable a purchase to be made. These arrangements may be supported by the UK Export Credit Guarantee Department and international banking institutions. Repayment periods can be from 3 to 6 years and interest rates are fixed at the prevailing concensus rate.

STROWGER EQUIPMENT

It is in the area of Strowger exchange switching that Teletrade has had most success by offering complete systems from 200 to 10 000 lines on a turnkey basis. Installation can be arranged in several ways by separate contract, using BT or local engineering staff.

In instances where local staff are employed, a highly qualified BT work supervisor is appointed to control the installation and thereby guarantee that work conforms to BT's own high standards. Because BT has had such a great experience in the installation and maintenance of Strowger equipment, it is well qualified to operate local training programmes. Additionally, instruction and advice is available to cover spare-parts holding, which is so often a vital part of the efficient operation of the system.

Teletrade's experience in providing exchanges has led it to offer a range of containerised Strowger systems. These



Containerised Strowger telephone exchange

† Teletrade, British Telecom International

are especially desirable for rural or outlying areas where there is no existing building capable of housing the equipment.

The entire exchange is housed in an insulated air-conditioned container. The units are fitted out in BT's own factories in the UK and are made ready for shipping to the remotest areas. All that has to be done locally is to connect a power supply and link up the existing network.

Once this has been done, the exchange is operational and ready to provide dialling facilities to people who may never have had them before. This type of containerised unit can act as a catalyst to a country's unity and development in a very simple and economical form.

The containerised system is modular in concept and based on a unit of 400 lines. Expansion to 900 lines can be achieved quickly without the need for larger power plant and, with the addition of further modules, the exchange can handle a total capacity of 5400 lines.

All the exchanges use a linked numbering scheme of 4 digits and all the units include relay-set functions across a parent exchange, trunk network capability and a manual board.

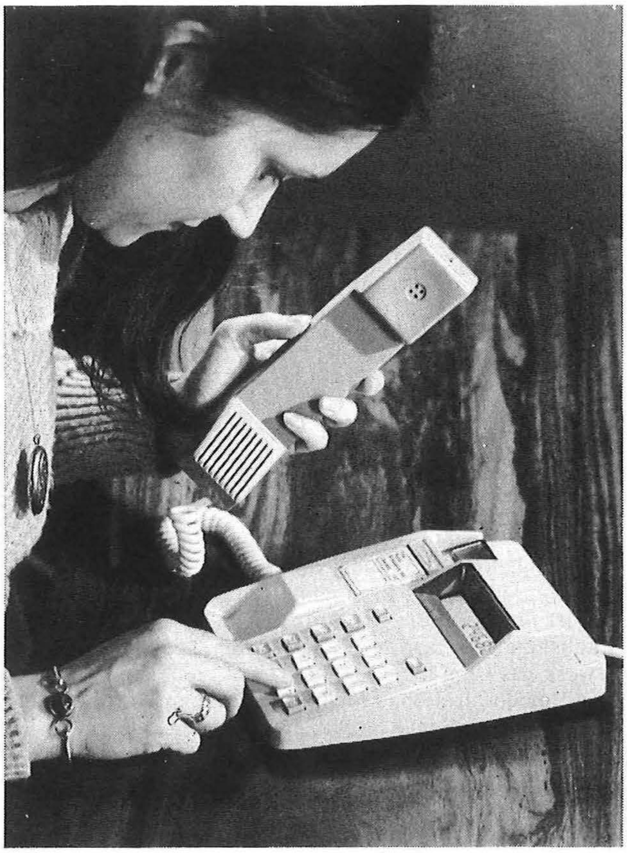
Each unit comes complete with a full set of tools, test equipment and the spares which will be required to ensure the smooth running of the exchange. In the construction of the unit, much consideration has been given to the hostile climatic conditions in which the equipment may often be used. So BT engineers have made the units as robust as possible and have designed them for ease of servicing.

Because the entire system is housed in a standard transport container, it is a simple matter, should the need arise, to relocate it almost anywhere.

TELETRADE CITY BUSINESS SYSTEM

The differing stages in development of the telephone systems in various countries have led Teletrade to expand its range to include several high-technology products, including what has been called the ultimate business communications system—the *Teletrade City Business System*. This was developed initially for those involved in currency or commodity dealing or any other fast-moving trading activity, where information availability and communication of that information must be speedy and accurate. The system combines a comprehensive telephone service (international, local and internal) with a compact display terminal that can call up computerised information and both send and receive Telex messages. A technical description of the system is given in another article in this issue of the *Journal*†.

Teletrade City Business System



Sceptre 100—an all-electronic telephone available through Teletrade

The user makes calls by touching the appropriate key which appears on the user's screen. The touching action is detected by a completely harmless curtain of invisible infrared light beams that activate the user's instruction.

When computer data is required, it can be requested in the same way and displayed on the top portion of the screen. A keyboard can also be added, to act in place of, or in addition to, the visual display keyboard. Telex messages can also be sent.

The City Business System is remarkably versatile, and can be tailored to each customer's requirements. It is a replacement for Key and Lamp and other similar systems, but one so advanced that it makes them, and electronic dealer boards, seem quite obsolete.

The screen can display up to 64 keys at once; in all, 2000 are stored in the computer's memory. These keys provide a multi-line network allowing access to exchange lines, private circuits or switchboards. Each key can be labelled to act as a telephone number, as an extension or call hold, as a keypad for dialling numbers not held in the memory of the system, or as a special line for confidential or security use.

Any number of lines can be connected to the system, and to make, hold or release calls the relevant key or keys are touched. The capabilities of the system allow more than one caller to be involved, and for the user to make calls while other activities are in progress; hence 2 handsets are provided for each work station.

† FRENCH, D. J. The City Business System. *Br. Telecommun. Eng.*, Oct. 1983, **2**, p. 174.

One facet of the system, which will be of great interest to users who make calls to the same person very frequently, or who tire of dialling multi-digit international codes, is the abbreviated dialling function. This gives access to a library of short code numbers of 2 or 3 digits and makes connections fast and considerably less tiresome.

As previously mentioned, the top half of the screen can be used to display information stored in the computer's memory. This data could include details on any part of the user's business and it can be edited or updated, on the separate keyboard, at any time.

The computer can hold up to 5000 pages of data on its disc memory, and this can be accessed from the user's computer, or from any other machine to which it is linked. In practice, the double-function screen allows users to call a client and then call up the relevant data which might be needed during the conversation.

The screen keyboard can also be used to compose, edit or store Telex messages. Transmission is at the touch of a key. When a message is being sent to the user, it can be either received and/or stored, depending on circumstances. If a message is received while the user is operating the system, a signal is given and the appropriate action can then be taken.

Another very useful facility which the system offers is the ability to receive or transmit data to other databases, installations or third-party computers. This invaluable option enables users to create very large information files made up from several different sources

Each Teletrade City Business System is assembled and fully tested by engineers in the UK to ensure that it conforms to the user's requirements absolutely. To make sure that installation takes place without hitches, a BT expert travels with the system and supervises the entire installation.

In the unlikely event of a system malfunction after installation, the built-in diagnostics identify faults so that any hardware or software problems can be quickly rectified by the local specially-trained engineers.

Depending on the particular requirements of purchasers, a number of special options can be specified to increase the versatility of the system. These might include keyboards, main-frame computer interfaces or equipment to allow the system to act as a terminal for an in-house minicomputer.

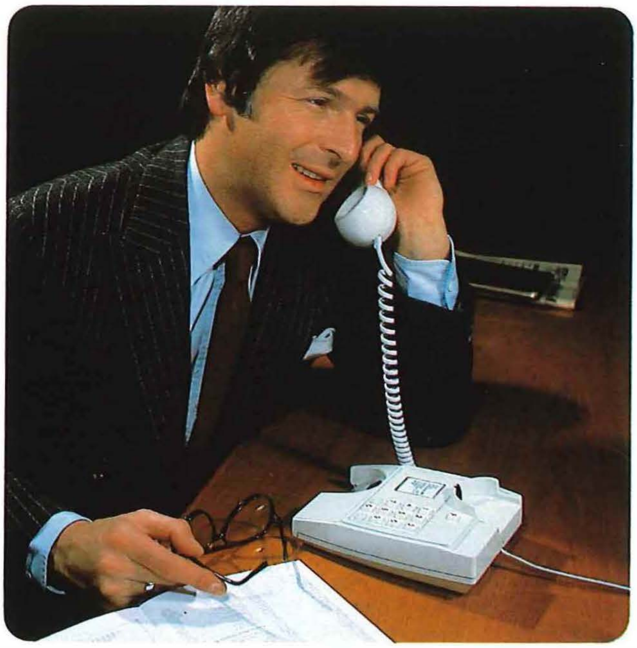
Additionally, Teletrade can provide loudspeakers as well as furniture and consol systems designed to enhance the smooth running of any organisation's procedures.

With the Teletrade City Business System, customers can acquire the most advanced equipment available, along with Teletrade's field-proven support service. Telegrade's experience in supplying a whole range of BT's equipment means that anyone buying any of its products will be sure that they are getting not only excellent hardware, but also the understanding and experience which Teletrade is able to pass on.

THE FUTURE

Teletrade began as a group selling Strowger exchanges and associated equipment, but it has now developed a much larger product range. It, thereby, has met customers' demands to the full and now frequently provides systems of a composite nature. These consist largely of electromechanical exchanges which form the heart of very diverse systems, often combining equipment of very different ages.

Teletrade's marketing philosophy is to provide countries with telephone equipment which is suitable not only for today's needs, but which can be expanded and modified to meet tomorrow's objectives. As BT's equipment is replaced, so more and more will become available to other countries. This means that purchasers of refurbished items will always be able to have access to the used UK equipment. This will enable them to upgrade their systems, and for Teletrade to function as a viable business for many years to come.



More high-technology equipment from Teletrade—the Puma electronic teleprinter (top), and the Statesman—a low-cost all-electronic press-button telephone (bottom)

CONCLUSION

Teletrade's operations are providing work in the UK for BT's factories, and are generating a positive cash flow from exports. The success of Teletrade is due in no small part to the valuable help that it receives from BT area, regional and headquarters staff, who have responded in a very positive way to the scheme.

The purchasers of Teletrade's equipment are often countries which had a need to improves their existing telephone systems but, before Teletrade, very little hope of ever doing so. The positive way in which Teletrade is helping provides them with facilities which those in developed countries take for granted, but which for them represents one of the vital cornerstones to the development of communications and a better future.

Commercial Enterprise at British Telecom Research Laboratories

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UDC 621.3.001.003

This article reviews the recent developments in the exploitation of the expertise available at the British Telecom Research Laboratories at Martlesham Heath, Ipswich, and gives some examples of the way in which co-operation is developing between Industry and British Telecom.

INTRODUCTION

In the UK, the early telecommunications systems operated by the General Post Office and its predecessors must have involved a great deal of experimentation, but it is not until the 1890s that any specialised experimental teams can be traced. In 1909 or 1910, a formal Research Section was established under a Sectional Engineer working from the 'Experimental Room' in Headquarters—the embryonic research unit from which first Dollis Hill, and then, Martlesham Heath Laboratories have grown.

Since then, there has been a strong and continuing theme of experimental developments, of first-off field trials, research prototypes, coupled with more fundamental studies, aimed at future systems or at an improvement in reliability, cost, or performance of existing technology. Much work has been carried out to permit British Telecom (BT) to become a sophisticated purchaser, able to be specific, to select wisely and to stimulate new technologies when they appear on the horizon. The balance between the refinement of existing technology and applied research and development (R and D) into new techniques has changed over the years; at times, particular systems or technologies become established, and a plateau of achievement or an established practice becomes the rule. At such times, work has been concentrated on refinement, and on squeezing the utmost in reliability, performance, and service applications from the technology. In recent years, with the rapid upsurge of semiconductor technology, of optical-fibre communications, and the approaching use of universal digital communication systems needed in an age of information technology, there has been a sharp increase of activity, to deal with the new materials and processes, the new devices equipment and systems.

Software is now almost as much a predominant part of many developments, acting as the controlling and supervising component or as a processing procedure. More importantly for development engineers, it is a tool, in the shape of computer-aided design (CAD) or CAD/computer-aided manufacture (CAM) programs that speeds up the realisation of new designs, and makes it possible to achieve highly intricate custom-designed integrated circuitry. CAD, by being applied to software itself, also permits programs to be defined at higher levels and to be written in a structured and logical way so that they can be automatically produced as low-level code routines.

However, British Telecom Research Laboratories (BTRL) is no longer staffed by a few professionals backed up by a larger team of laboratory assistants and field staff, using a fairly standard set of precision measuring equipment. Today's teams may not be very much larger in professional content, but their supporting equipment is much more extensive and expensive, and sometimes purpose built. A systems team developing a new service or new equipment can be large, involving perhaps 20 or 30 staff, or more if extensive field trials are contemplated. The very scale of investment in equipment and the numbers and training of expert staff, coupled with the very rapid change in technology and the cross-fertilisation between different disciplines, make it difficult for small and medium-sized organisations to keep up to date, even though they may specialise in a restricted area.

Aerial view of the British Telecom Research Laboratories

In the past, much of the development work of the BTRL has been directly aimed at supporting intended development contracts with Industry. But, with the new commercial stance of BT, and competition in many markets, Industry is being asked to carry out its own commercial developments. This does not imply that advanced design work is lessening within BT, for most projects are now supported by operational departments in order to demonstrate new designs and systems. But more and more companies find that they can benefit from the work carried out by BTRL, by obtaining designs and software on a commercial basis.

As part of this new stance, there is benefit to BT in making available to companies, particularly the smaller organisations, the fruits of its R and D work, in order to widen the supply base. This applies particularly in the terminal and ancillary-equipment fields. Development work tends to disclose some fundamental problems; a lack of suitable material, or of a piece of test equipment, or of a tool or technique, and such items (generally known as *fall-out* items) can become a key product for a specialist manufacturer.

† Technology Executive Liaison, British Telecom Major Systems

In this new commercial environment, a number of new commercial arrangements, loosely grouped under the term *consultative services*, are now available at Martlesham. The various arrangements are discussed in the following sections of this article, and examples are quoted of their application to specific cases. In all, they form a comprehensive portfolio to meet most needs and should form the basis for further exploitation of resources of the BTRL, should this be needed.

THE TECHNOLOGY TRANSFER CLUB

The first scheme to be implemented was the 'Friends' scheme, the *Technology Transfer Club*, specifically aimed at small companies wishing to expand or update their product range. For an annual subscription, a company becomes entitled to a limited amount of high-level consultancy, covering most of the available expertise. Obviously there is a limitation to the number of companies which can be accepted, particularly in certain hard-pressed areas, and intending members are asked to state their dominant interests to avoid the overloading of any one area. To some extent, this scheme merely puts on a commercial basis the kind of informal arrangement that many long-term suppliers have built up. It has the added advantage, from their point of view, of a firm entitlement, and strict confidentiality as to their commercial intentions, and thus permits much more open discussions. At present, there are 9 members of the scheme, and it seems likely that the demand, in present circumstances, will stabilise at around 10–12 members. Most interest has been shown in customers' apparatus, with some additional interest in expertise in advanced manufacturing technology.

CONSULTANCIES

More conventional consultancies for advice and reports on specific subjects or projects are also offered, and this area has generated some profitable business and established new contacts, sources of supply and other support. The fundamental limitation is resources, and work can be undertaken only if an expert is available and supported by past research and documentation into the subject. The consultant benefits from a widened experience, a sight of industrial problems and new contacts; this added value in return for the effort is valuable. Advisory work for Government, including long-term committee work, falls into this area. Quite a substantial income to BT has resulted.

RESEARCH CONTRACTS

Provided that the work does not clash with the direct needs of BT as a whole, and that resources are available, research at BTRL can be funded under contract by outside organisations. There have been proposals for research contracts from Industry, but none has been acceptable because of the internal demand on resources in particular areas. This does not, however, imply that all such proposals will fail. To date, several R and D contracts have been obtained for what is, in effect, shared support of work that is already, by and large, supported by BT. Indeed, it would appear that many tenders for R and D are invited on the assumption that full costs will not fall upon the purchaser. In particular, 2 contracts (to be discussed later) from INTELSAT for work on radio propagation for satellite systems have been obtained.

SALE AND HIRE OF SPECIALISED EQUIPMENT

As part of this normal role, BTRL has set up sophisticated test facilities and developed or acquired specialist test apparatus. A small but increasing income is now being received from the hire of specialised apparatus, and for the use of specialised test facilities. Where demand is small, as in the early stages of a technology, some very specialised laboratory test equipment has been sold.

The Martlesham 6 m diameter steerable aerial used for propagation studies

MARTLESHAM ENTERPRISES

Many research centres and universities, particularly in the USA, have *science parks*, where *campus companies* have become established. These utilise ideas from the parent organisation and are able, because of the expertise and facilities readily available in that organisation, to develop and expand in new technologies.

While all of the work at BTRL is directed to the requirements of BT, there are some fall-out items, such as new materials, new techniques, new devices, and ancillary and test equipment, which are not directly required by BT, and which BT sees no need to support in its development phase. Furthermore, from time to time, particularly when projects have been discarded, some strongly entrepreneurial individuals, mostly high-quality staff, have left BTRL, and usually emigrated.

It was felt that, if there was a vehicle to pick up such fall-out items and to assist financially with the setting up of a new company and the supporting of it in the development phase, then the ideas and enterprise would not be lost to the country, and a new source of wealth and employment could be created.

Experience has shown that this is a long-term venture, for such arrangements have generally taken a decade to become well established. However, it was hoped that BT's participation in the venture (it holds 30% of the capital in Martlesham Enterprises Ltd.) would be something of a support to any intending entrepreneur. Secondment, if wished, rather than irrecoverable transfer, is offered to staff, who would gain from the experience of management in a small business, which should advance their careers if they chose to return.

The secondee must have the necessary expertise to ease the transfer of technology, as well as a venturesome spirit and, to date, no scheme matching these qualities to a viable enterprise has been put forward. However, Martlesham Enterprises Ltd. has formed a portfolio of selected small businesses and is matching fall-out items with these businesses, and is aiming to assist with the development phases of the new ideas. A new process for precursor chemicals for the manufacture of indium phosphide, of semiconductor quality, needed for longer-wavelength laser manufacture, has been placed with a small chemical company in Durham. The company was in the process of reconstitution and needed a completely new range of products; it is hoped that this development will begin a range of analogous products, some from Martlesham.

One swallow does not make a summer, but it is fair to say that a couple of dozen projects were examined and discarded, for one reason or another, and further possibilities are in hand. Looking back, there were definite possibilities in the past; the future is difficult to predict. This scheme is no charity arrangement, it is a strictly commercial, albeit a high-risk high-reward venture, aimed at strengthening the manufacturing base of this country in advanced technology.

VENTURES

As part of these activities, BT's Technology Executive Liaison Division (TEL) has been drawn into some proposals for joint ventures or franchising between BT and outside organisations. The circumstances are usually thus: there is an idea or product within BTRL that BT as a whole cannot exploit rapidly because of other commitments, and it seems that some outside co-operation would seize the market that exists. TEL's role has been that of a catalyst; it has been possible to bring things to a head, to help with proposals, and to bring interested parties to each other's notice.

LICENSING

TEL acts to market licences and, where appropriate, to negotiate terms for the transfer, under license, of intellectual property. Many small developments (for example, tools, computer programs and instruments) are licensable, but it is often necessary to carry development to the point where an identifiable product can be transferred, clearly and smoothly, to the licensee.

The greatest returns for licences concern equipment or processes that are demonstrably viable, and that have been successfully developed and brought to the market. Such items are rare in BTRL; in general, licences are concerned with an innovation that requires considerable development and marketing before a profitable venture is formed.

However, with the increased pace of change and the increased willingness shown by operators to embrace new technology, several items, developed as part of feasibility demonstrations, have proved attractive to companies wishing to develop new systems. If this trend continues, then all concerned with such work will tend to aim their demonstration equipment towards production. Modern technology is tending to this end with compatible CAD/CAM systems and with software following the same pattern.

PUBLISHING

For many years *Research Reports*, regarded then as a major component of the output of the Research Department, were freely circulated on a very wide basis, and copies provided (subject to commercial safeguards) to industry at home and abroad. Such reports are no longer published, but past reports are available for a handling fee. The reports have been replaced by a quarterly journal, the *British Telecom Technology Journal*, the first issue of which was published in July 1983, and has been circulated on a selected basis. This, it is hoped, will develop into a commercial venture. However, some larger internal reports have external value and, for that reason, present an opportunity of publishing for profit. The numbers are likely to remain small, although it is possible that some aggregations of internal memoranda dealing with subjects could, with minimum effort, be turned into a commercial proposition. In practice, such publications are often market led, the demand arising because the existence of the work becomes known.

SEMINARS

In some areas BTRL acquires specific knowledge, usually system expertise, possibly associated with international and national standards of a service, which is most easily disseminated through a seminar. For example, the first seminar put on by BTRL was concerned with Videotex standards; others will occur as and when the opportunity presents itself.

One approach is to share a seminar required by BTRL from some acknowledged authority with selected companies and universities.

RECENT ACTIVITIES

To gain a better appreciation of what has been achieved in 1982–83, and some idea of the range of activities covered, some broad headings of activity and some of their associated commercial achievements are considered and noted below.

Semiconductor Devices

The most significant commercial activity in semiconductor devices is the production of transistors (the Type 40) for conventional submarine coaxial-cable repeaters. However, the same technology, proven over many years, is being extended into very-fast emitter-coupled logic circuits, suitable for digital regenerators operating at speeds of up to 560 Mbit/s, and may well continue the tradition by appearing in commercial optical-fibre submarine systems.

An in-house facility for the fabrication of n-channel metal-oxide semiconductor (MOS) integrated circuits has been

Loading an electron beam micro-fabricator used in the manufacture of integrated circuits used, helped by an in-house-developed interactive-graphics system to produce a design for a *filter-and-detect* (FAD) chip. This chip was intended for and used in System X to detect the tones emitting from the voice-frequency signalling systems of press-button telephones. However, because the filter coefficients that determine the response of the active sections are fed from a read-only memory, it is a device of great versatility, and provides a way of introducing a wide range of uses for digital filters. The circuit provides for 8 second-order sections operating at 8 kHz.

The FAD chip is under an option for license and, to stimulate the market, a small production run has been ordered and quantities are available for sale, together with designer information, from BTRL.

Optical Transmission Systems

Originally, work at the BTRL on glasses for fibre optics concentrated on borosilicate glass, using a double-crucible process, aimed at making a cheap and robust guide for low-rate (2 Mbit/s) systems in the local network. The success of this system, which has been licensed, has tended to detract from other, later, achievements in the production of monomode fibre using the modified chemical vapour deposition (MCVD) process. By modifications to the process, which permit lower temperatures to be used, the geometry of the resulting fibre has been much improved, and the modified process is attracting commercial alternatives.

As part of the fundamental work on optical systems, much attention has been paid to the production of semiconductor-quality layers of indium phosphide, particularly for lasers for the longer wavelengths. Because of inherent difficulties with the existing process, which required the use of difficult-to-make and pyrophoric starting chemicals (alkyls of the 2 elements), a new process was developed using new precursor chemicals—*adducts*. In conjunction with Queen Mary College, London, working under contract, a technique for the production of these indium and phosphorus adducts was developed. This manufacturing process, together with a processing kit and knowledge for manufacturing small trial slices, forms the kernel of the licence given through Martlesham Enterprises Ltd. to the company in Durham (Thomas Swan, of Consett). As far as can be judged, this process is showing good commercial promise, with sales in the USA and Japan achieved within a month of the first batch production.

Other items under license in this area are techniques in more conventional metal oxide chemical vapour deposition (MOCVD) processes for semiconductors, and improved arrangements for the control of liquid-phase expitaxy applied to semiconductor slice production.

A good yield in device production depends on good material. For this purpose, an infra-red spectrascope has been developed and is now commercially available under licence (SIRA). A commercial development of long standing—a plotter of carrier-concentration profiles in semiconductors—commercially marketed by Polaron Ltd., requires certain precision rings to be employed and there is a small and steady demand on the supporting workshops at Martlesham Heath based entirely on product quality.

In optical-fibre systems, the advanced systems produced at BTRL stand up in performance to the best reported in the world. For example, a 140 Mbit/s unrepeatered system of 102 km length using monomode fibre was demonstrated in January 1982. This used the matched-cladding monomode-fibre design which has been adopted by Standard Telephones and Cables plc (STC) and the General Electric Company plc (GEC). The BTRL design of 1·3 μm and 1·6 μm PINFET receiver is now available from Plessey plc. The loose-tube fibre cabling system has been incorporated in commercial designs. Monomode splicing machines of BTRL design are in pilot production, and a monomode optical time-domain reflectometer has been manufactured in small quantities.

To support the development work on fibre-optic submarine-cable systems, a range of specialised test equipment has been assembled: high-pressure chambers, a tensile and vibratory test rig, and an artificial ocean of high-pressure pipes into which a cable can be drawn. Essential as this equipment is to submarine-cable development, it is also applicable to a number of other fields, and some of the facilities have been leased on a number of occasions.

As might be expected from a new field, a number of basic instruments have been developed by BTRL and have been licensed. These include a monomode-fibre jointing machine using the fusion process, a design of cleaver for preparing fibre ends for jointing, and a version of the optical time-domain reflectometer operating on monomode fibre at long wavelengths.

Radio Systems

The radio laboratories at BTRL have always had a strong practical bent, being from the outset concerned with field trials, demonstrations and working designs. Indeed, for many years, they relied for fundamental research on other sources, and concentrated entirely on system work. That being so, the experimental earth station at Martlesham Heath is used for propagation work with satellites and has built up a reputation for high-quality well-calibrated observations and reliable statistics. Surprisingly enough, although situated in a relatively dry area (for the UK), it does experience high-density rainstorms, and is thus suitable for work at the frequencies from 11 GHz upwards. Supporting contracts have been received from INTELSAT for work in this area, in conjunction with the INTELSAT V satellite over the Indian Ocean and operating at 11–14 GHz. The object will be to record the depolarisation and the simultaneous up-and-down path attenuations.

For some time, a series of experimental satellite business systems have been operated, using mobile small-dish satellite equipments, and operating at 11–14 GHz using the Orbital Test satellite. Some development work, essential to such experiments,has resulted in a range of designs that have been offered for licence; for example, a printed-wiring board

Installation of a small-dish antenna on the AMOCO *Montrose Alpha* oil production platform in the North Sea

(PWB) version of the DES encryption algorithm, a 2-phase-shift-keyed (PSK) 2 Mbit/s modem, and a single-channel-per-carrier access equipment. The equipment is designed for future services using 12–14 GHz, and operating over the EUTELSAT and TELECOM I satellite systems.

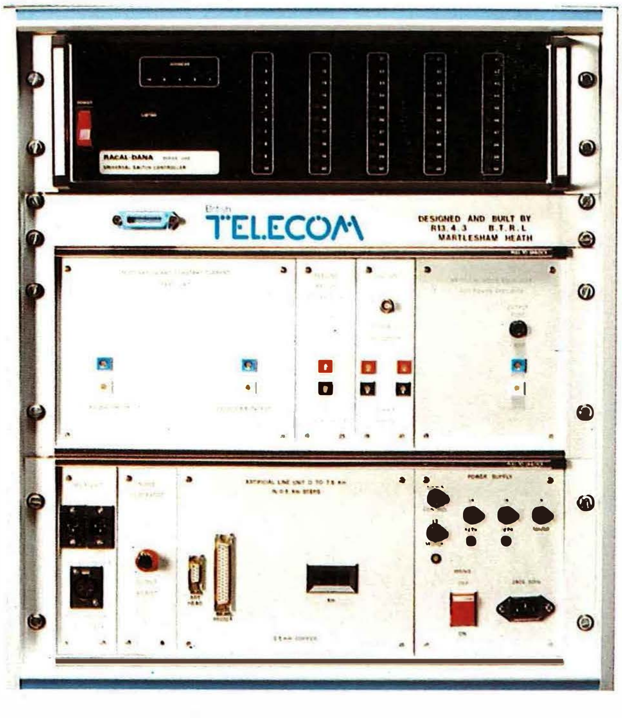
Switching Systems

The Monarch design of digital private automatic branch exchange (PABX) dated back several years to an experimental version produced at BTRL. Monarch is now in licensed production in the UK market and, during 1982, the fundamental designs have been licensed for overseas markets. This is an example where, because a comprehensive development programme has resulted in a tried and marketed product, the licensed package is attractive to manufacturers, not only for the UK and for export, but also to overseas manufacturers for their domestic market. This particular design concept is far from exhausted and should lead to further interest.

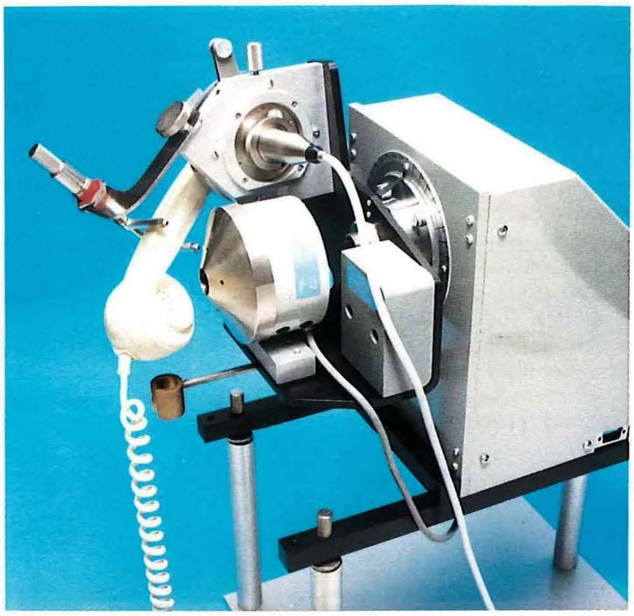
Terminal Apparatus

In recent years, telephone instruments, hitherto regarded as a standard utility item, have become a consumer article and, with the new market freedom coming into being in the UK, BT has begun to widen its range on offer and to incorporate new technology to increase customer appeal. BTRL has been involved in these developments, notably in the Viscount range developed in co-operation with STC, and has produced, as an internal development, an advanced-design telephone, the *Sceptre 100*, incorporating a number of additional facilities. This work has required the development of advanced computer-controlled test facilities, both for production and for basic type certification, and these equipments have been supplied to manufacturers. The TIGGER test equipment forms the basis of the type-approval systems operated in the recent past by BT, and now provided by the British Standards Institution on behalf of the British Approvals Board for Telecommunications

For the business user, the BTRL has, in conjunction with its system and protocol development work, produced an



The TIGGER telephone transmission performance test equipment


Loudness rating guardring position jig used in conjunction with the TIGGER test equipment

example of a Teletex system.This operates to the full CCITT† Roman alphabet, over the public switched telephone network and the BT Packet SwitchStream (PSS) service. The basic communications program, which was written in PLM86, running under the proprietary Intel operating system RMX86, has been licensed to a UK company. A version, hosted on a BTRL PWB design, running under the simpler RMX 88 operating system, and providing layers 2–5 inclusive of the protocol, is now available. This permits an OEM solution for the adaptation of commercial terminal equipments, inputting according to the CCITT V24 Recommendation and, at the output, operating dial-pulse signalling and connecting to the normal 2400 bit/s modem. Adaptations for the integrated digital network, and for BT's PSS service are becoming available.

Visual Services

A trial of videoconferencing, operating over a 2 Mbit/s digital network, is beginning, and a COST* 211 standard 2 Mbit/s codec has been devised and quantities for the trial purchased. Modems have been supplied to overseas operators for international and internal trials. They have an impressive performance and represent an advance on earlier solutions, and have been licensed for manufacture within the UK.

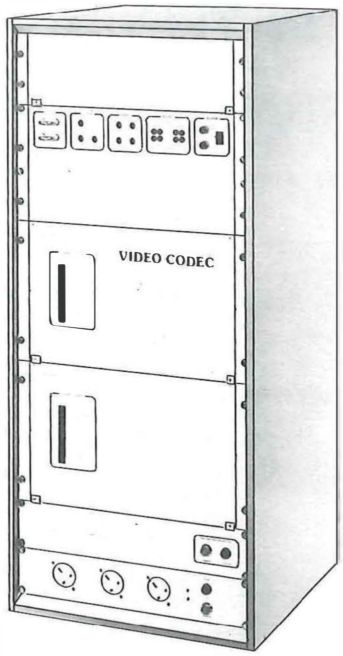
Videotex Systems

Videotex systems (viewdata) are the basis for a wide range of business systems, not all hosted on the Prestel public service. Several consultancies have been arranged to give advice and support, one for a system abroad, and a wide interest is still displayed in this market. Because of the intricacies of the negotiations at an international level, a special seminar attended by some 100 people was given in London in early-1982.

† CCITT—International Telegraph and Telephone Consultative Committee

* COST—European *CO*-operation in *S*cientific and *T*echnical Research

A demonstration Teletex terminal operating the full 308-character alphabet for 40 latin-based languages



2 Mbit/s codec for videoconferencing, 625/525 colour standards

Equipment Practice

If closely controlled, plastic encapsulation of devices is sufficiently reliable for use in many parts of a public telecommunications system. A need was seen for a cheaper chip carrier, which would permit on-carrier testing of an integrated circuit, would permit subsequent plastic encapsulation, would give sufficient protection for auto-placement using surface vapour phase soldering to the host PWB, and would be capable of good heat transfer. A design of chip carrier, using epoxy-glass PWB laminate for its base construction and PWB plating, and plated-through-hole technology for the necessary contact pads, was developed at BTRL in conjunction with Tectonic Ltd; this has now been licensed for industrial production. Automatic testing of on-carrier integrated circuits is a service offered commercially at BTRL, and has been used extensively to support manufacture for BT.

Software Design

Software is a dominant activity in the design and development of modern switching systems and in many terminal appliances. It is no surprise, therefore, to find 2 products, developed for use within BT, but now available on license, which are aimed at reducing the routine burden of writing software. The first, designated *SX1-CADOS*, is subject to an agreement with the British Technology Group for its development and marketing in all markets. The system originated in a research contract placed with Essex University. As now implemented, it permits the designer to work in graphical formats (for example, CCITT SDL), and high-level language programs can be generated when the structured graphical documents are satisfactory. The programming languages at present available are CORAL, PLM and PASCAL. The technique brings a degree of engineering discipline to software design. Major quantitative and qualitative benefits have been obtained.

An alternative process, using design structure diagrams, is also available under licence from BTRL. This process generates PASCAL88; other language compilers are in the course of production. Documentation is produced automatically.

Human Factors

As a final example, BTRL's work in human factors, originally applied to telephony, is now much more widely based. It has attracted interest, in consultancy, for its expertise on all man–machine and operational interfaces, visual, manual (particularly keyboards) and voice. There is a continuing demand for a publication, a Research Study entitled *Man–Machine Dialogue Design* by Dr. Alison Kidd, a member of the Research Department. This is basically an extensive survey which has found application as a textbook for some types of general courses in this area

CONCLUSION

The previous section is something of a catalogue, listing some items that have been exploited commercially in 1982–83. There are many other activities in hand of equal interest (some of which are, naturally enough, commercially confidential to BT), which have applications as the subject of a consultancy, or which are impending as a product for sale or license. That the commercial exploitation of the activities and expertise of BTRL is viable has been demonstrated; research contracts, in particular, are a valuable financial support, and consultancies widen the expertise of the consultants. Licensing can give a return in many areas, but it is most effective where a packaged market-proven product can be defined. The remaining activities merely commercialise information transfer that is essential to the industry as a whole.

All these activities can serve BT and its policies, and secure a better manufacturing base and influence standards in what is becoming a competitive yet interactive and interchanging service.

Much of this reported activity depends on individuals, the consultants and designers, who have to put that additional effort into understanding others' needs, to document and to bring these goods and services to a marketable state. Licensing relies heavily on the Intellectual Property Unit of BT.

Finally, the business generated is non-recurrent; it is a question of finding and making opportunities with what is to hand. But commercial relations can form much more effective links for technolgy transfer than more informal arrangements and, without that transfer, a significant lag between research and manufacture would occur. Such technology transfer is in the best interest of BT.

LONDON TELECOMMUNICATIONS

The City Business System

D. J. FRENCH, B.SC.†

UDC 621.395.2 : 621.39 : 681.31

This article describes the unique City Business System designed by engineers in British Telecom London City to meet the needs of London's business trading community. The system has a terminal with a touch-sensitive screen which enables users to access private circuits, exchange lines and private switchboards, as well as a range of computerised information. From the same terminal, users can use remote computers and access the Telex network, the packet-switched network and viewdata systems. The system is an interesting example of the convergence of computer and communications design.

INTRODUCTION

Since 1976, British Telecom (BT), specifically BT London City, has supported the needs of London's financial institutions to combine very large numbers of telephone lines at dealing positions. Early products used illuminated keys with engraved labels to gain access to the lines but required major installation effort. A large system could take as long as 6 months to install and was very inflexible in regard to facilities and the movement of lines.

Simple inspection of a foreign-exchange dealer's cluttered desk indicated the need for a single device to perform a wide range of telephone operations: public switched telephone network (PSTN) calls, private tie lines, intercom, autodialling, loudspeaker monitoring and many others.

Data displays were in frequent use and some companies had brought full computer access to dealers' desks. A considerable amount of supporting activity was taking place over Telex. Therefore, the possibility of combining the speech, computer-access and Telex facilities was investigated. This wide range of operations required a display that was very fast and flexible and an input device that complemented this flexibility.

Evaluation of the alternatives led to the use of a high-resolution video monitor coupled with a touch-sensitive input device mounted over the face of the cathode-ray tube. By attaching a full ASCII keyboard the full facilities of a visual display terminal were made available, and this made it possible for the system to give access to almost any remote computer or message-handling system.

The development of this system began in late 1980, and the first installation entered service in July 1982 at Williams and Glyn's Bank in the City of London. Since then, many systems have been installed in the UK and overseas. The ability to combine flexible telephony, Telex and data-terminal capability can be used in a number of other applications, including automatic call distribution (ACD), emergency-service co-ordination, utility control centres and airport services. Fig. 1 shows an installation of 48 dealing positions with a 400-line multiple that was recently supplied to Godsell and Co.Ltd., a London foreign-exchange dealer.

OUTLINE SYSTEM DESCRIPTION

The user sits in front of a terminal comprising a visual-display-unit screen and detachable ASCII keyboard. Up to 8 terminals are grouped in a cluster driven by a terminal cluster processor (see Fig. 2). Large systems can be configured by using many terminal clusters.

†British Telecom London City

FIG. 1—City Business System installed at Godsell and Co. Ltd., London

The terminal cluster processor generates video signals for its terminals and polls the terminals in turn for operations. A typical picture is a matrix of 64 keys each with a unique label. Infra-red beams passing over the surface of the screen detect when the centre of a key is touched, and this is interpreted as a key depression. As a key operation is reported it is compared with the video image being created to determine the implied action to be taken. This can involve a simple local operation to change the video image or generate a command to other components of the system via the inter-central-processing-unit (inter-CPU) link.

Several operations involve fetching data from a disc storage system. The raw data defining key layouts are stored in 1 Kbyte files; also, 2 Kbyte information pages and short-code dialling and external telephone line definitions are stored on disc. Commands are sent by the terminal cluster processor to the disc handler processor, which deals with each transaction and sends the requested data back to the originating cluster over the inter-CPU link.

Commands from the users' terminals to operate on lines (for example, SELECT or RELEASE A LINE) are sent from the terminal cluster processor over the inter-CPU link to the switching control processor; this makes the fundamental telephone protocol decisions and implements them by sending instructions to the matrix subsystem(see Fig. 3). The

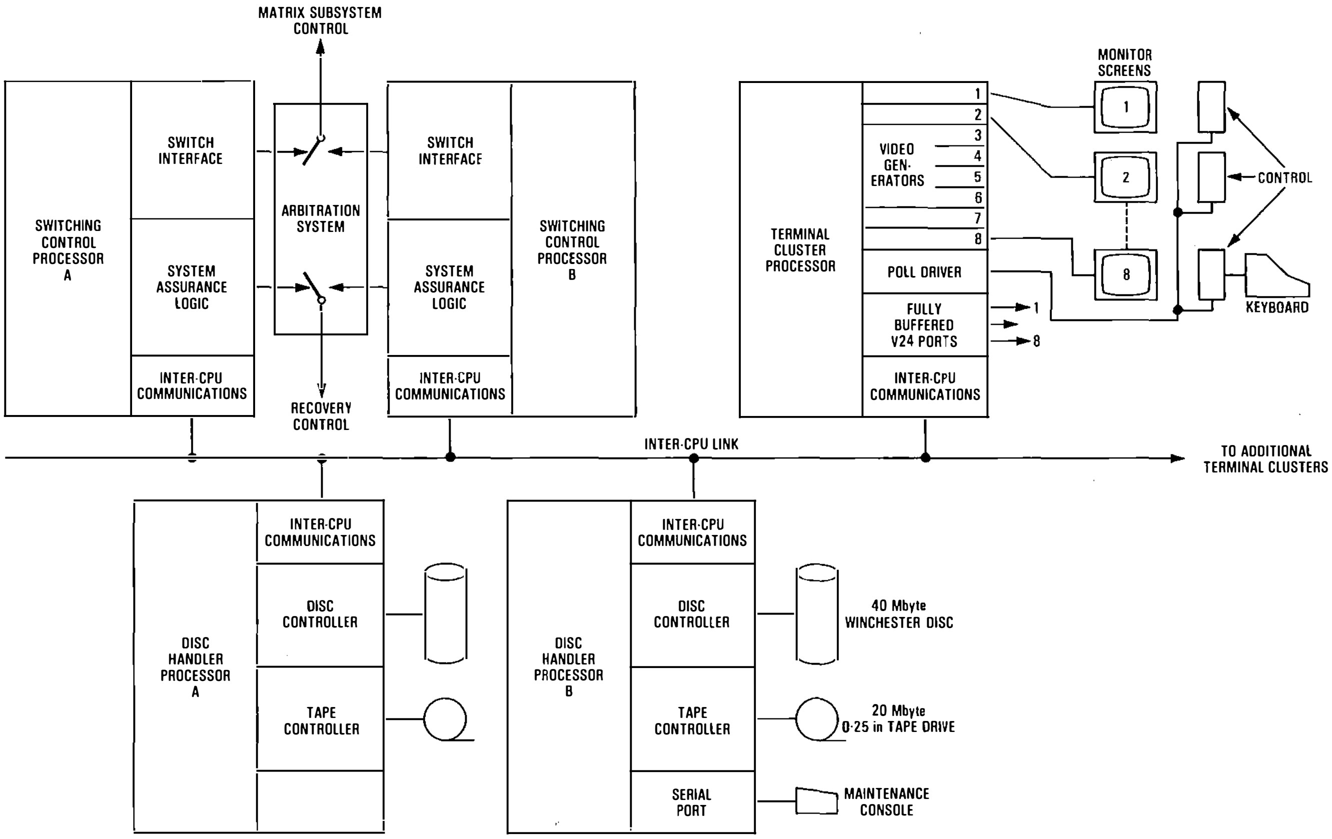


FIG. 2—Block diagram of the City Business System

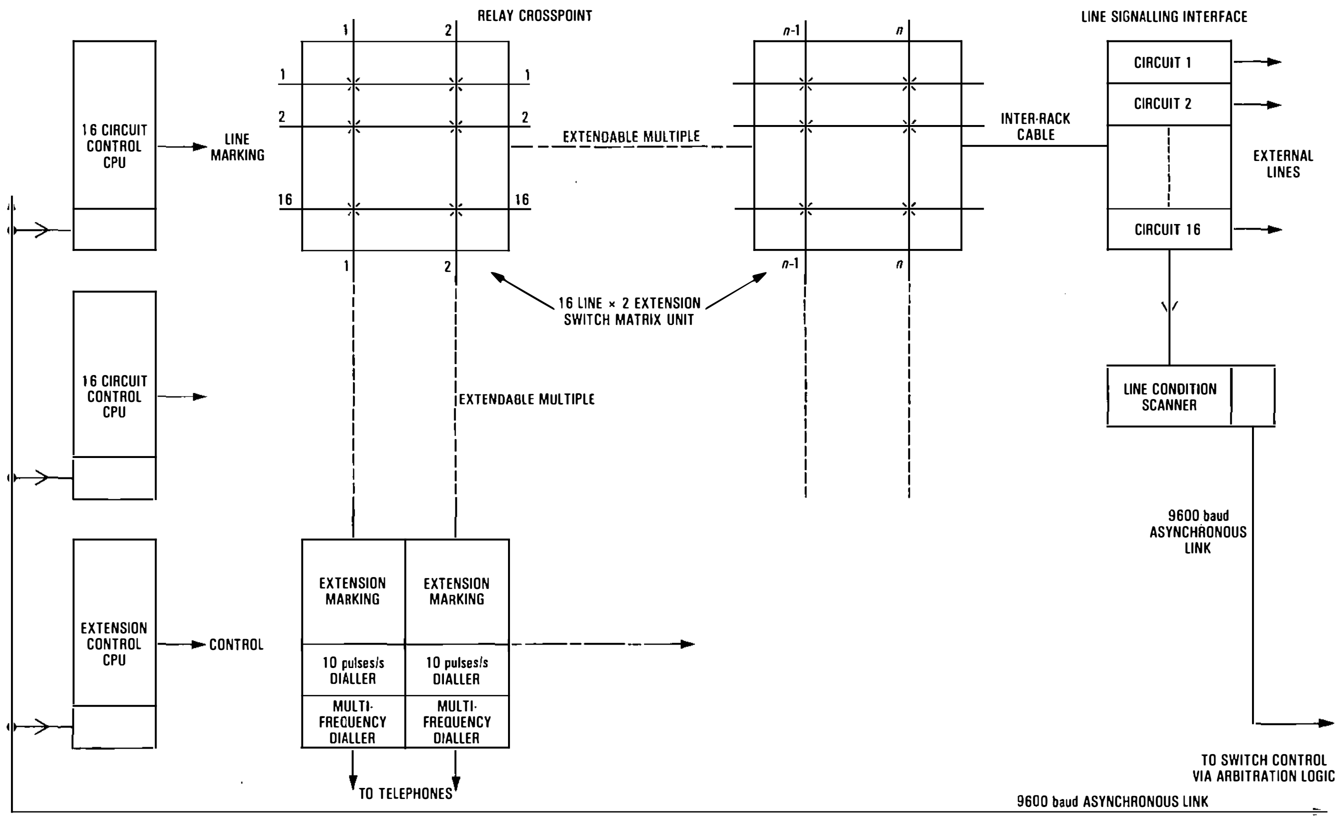


FIG. 3—Matrix subsystem

switching control processor also receives status information from the line-condition scanner regarding incoming calls; this leads to instructions being sent to the terminal cluster to signal to the user.

The matrix subsystem is a matrix of miniature relays with a module size of 16 lines by 2 extensions. Both the line- and position-multiple directions can be extended. Each group of 16 circuits has an intelligent marking processor, which passively monitors a data link from the switching control processor. The extension marking is achieved by the combination of an intelligent processor and a marking/register interface board. This gives full dialling availability to all extensions simultaneously and no possibility of switching congestion.

THE TERMINAL

The terminal consists of a metal framework containing a high-line-rate monochrome video monitor which has 440 scan lines refreshed at 50 kHz; this gives a clear display of 40 lines of alphanumeric or graphic data.

The cathode-ray tube used has a medium-persistance green phosphor and a 28 mm neck to achieve high brilliance. The face of the tube is fitted with a 10 mm bonded etched faceplate. This has the dual advantages of improved safety and a degree of elimination of reflections.

Mounted over the front of the tube is the touch-sensitive device. This has a curtain of infra-red beams passing near to the surface of the screen in an 8×8 matrix pattern. The crosspoints are aligned in the centres of 64 key areas on the video screen. An interruption of one vertical and one horizontal beam represents operation of the key at the intersection.

The infra-red transmitters and receivers are mounted on a printed-wiring board (PWB) wholly contained within a translucent 3 mm polycarbonate surround which is screwed into the front of the monitor housing. Despite the considerable difficulties caused by the absorption of the light by the plastic material, it was considered well worth the effort to avoid the use of specialised filter materials.

The transmitters and associated receivers are driven by a microprocessor contained on a PWB within the monitor. This deals with scanning and debouncing the touch system. It also has ports for attaching peripherals: 2 asynchronous ports to interface with keyboards, bar-code readers, printers etc.; and 2 parallel ports to interface with specialised keyboards and customised facilities. The microprocessor also deals with code conversion from the attached peripherals, enabling virtually any keyboard or input device to be used.

The terminals are connected by a 4800 baud polled asynchronous multi-drop data link to the terminal cluster processor. Up to 8 terminals can be connected to a cluster.

The modular nature of the monitor will allow the use of new technology as the development of touch-sensitive devices progresses. Many areas are being explored, but these usually involve an additional plastic or glass plate mounted above the tube, which gives an unacceptable visual effect.

SCREEN LAYOUT

The screen is normally used with a matrix of 8×8 keys displayed (see Fig. 4). The bottom line of the display is used as a status line and has date, time-of-day and remarks fields. The remarks field is used to help the user through a complex operation, to display a number being keyed or a short code, and to give error reports following an illegal operation.

Each key displayed is made up from a number of surrounding graphic elements (see Fig. 4). Different status conditions can be displayed by altering any of the 8 graphics fields. A number of special characters can be used as well as attributes such as flashing (2 speeds), video level (4 levels), inverse video and strike through.

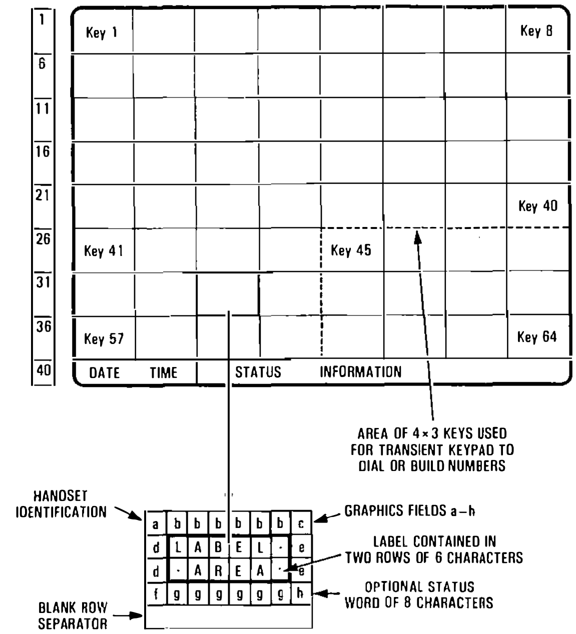


FIG. 4—Screen layout for a full key page and key composition

TABLE 1
Line Condition Indications

Line Conditions	Label Attributes	Surround Attributes	Notes
FREE	Normal bright	Thin line grey	
BUSY TO ME	Normal bright	Thick line bright	
BUSY TO ANOTHER	Inverse grey	Thin line grey	
BUSY PRIVATE TO ME	Normal bright	Thick line bright	PRIVATE under key
BUSY PRIVATE TO ANOTHER	Inverse grey strike through	Thin line grey	
HELD BY ME	Normal bright	Thick line bright	HELD under key
INCOMING CALL	Normal bright	Thick line flashing	

As it is rather difficult to appreciate more than 5 or 6 different status conditions using the video attributes, some infrequently used conditions are displayed by using the bottom line of the key to display a status word.

Although the system is fully programmable, a set of standards has evolved. Users were found to prefer rounded corners to keys. Thin line surrounds are used for line functions, and thick lines for control functions. If 2 handsets are being used with the monitor, the handset number is displayed in the top left-hand corner of the key. The line-control indications are given in Table 1.

The 12 keys in the bottom right-hand corner are available as a transient keypad. Irrespective of the layout being displayed, if an operation is invoked that requires the use of a keypad, it appears in place of the old keys. When finished being used, they disappear and are replaced by the original keys.

The top 24 lines can be used for data display purposes (see Fig. 5); this leaves 24 keys for telephony use and for the keypad.

Some of the main key functions are given in Table 2.

CENTRAL PROCESSOR

The central processor is made up from a network of microprocessors each performing a fundamentally different task.

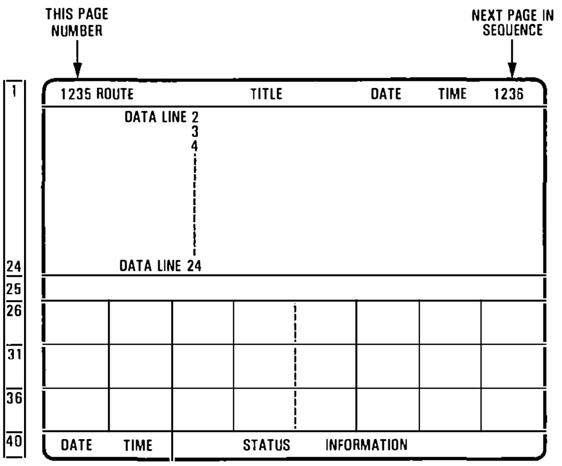


FIG. 5—Screen layout—data displayed

TABLE 2
Extract of Main Key Functions

Function Name	Action
KEYPAGE	Get the key page specified in the data field and put up on the screen replacing the present keys.
SELECT	Select the line specified in the data field.
RELEASE	Release the currently selected line.
HOLD	Hold the currently selected line.
RING/RECALL	Apply recall earth for 200 ms.
DATA PAGE	Get the data page number specified in the data field and display at top of screen.
PORT	Attach console to V24 port to commence communication to remote computer, message switch etc.
BACKTRACK	Step back to previous key page layout.
DIAL	Keypad digit.
CALL	Single-key calling—uses the short code defined by the data field.
SHORTCODE	Enables a short-code number to be keyed in at the keypad.
SAVEPAGE	Save the currently displayed data page in the disk data file.
NEXT PAGE	Fetch the next page in a linked sequence of data pages.
EXECUTE	Execute the data file specified by the keypad to update line dial or key disk files.
INTERCOM	Call another position on the system for intercom.
DYNAMIC	Available for use to display incoming calls on lines not already in the current display.
FLASH	Return line currently selected to incoming-call status. Useful form of transfer.

They intercommunicate with message packets over a high-speed serial data link. The 3 elements are: the switching control processor, the disc handler processor, and the terminal cluster processor.

Switching Control Processor

The switching control processor handles all aspects of telephony protocol. It is connected by serial data links to the matrix subsystem and the line scanning system.

The switching control processor holds data structures mapping the line and console statuses. Incoming messages arrive from key operations at screens. Each is dealt with in turn by a transaction-oriented program. The general validity of the message is first tested, and then the fine detail is checked against the status tables for legality. The command is then converted into a series of instructions and sent to the appropriate destinations: the matrix subsystem to effect switching operations, the disc handler processor to fetch archived data, or the terminal cluster processor to modify video images.

One particularly important function of this processor is to identify problems in the inter-CPU communications link. This is the usual symptom of failure of a part of the system. The switching control processor has the capability of isolating any CPU attached to the link and can thereby remove any disruptive processor from service. After reloading the program, the faulty unit can be returned to service. Thus the system is designed to recover from all software design faults, and this has been substantially achieved.

As the functions performed by this processor are essential to the operation of the system, 2 identical devices are provided. A simple arbitration device notes a failure in switching control processor A and diverts the control ports to allow processor B to take over operation of the system.

Although the switching control processor is in overall command of the system and is therefore the logical place to attach the maintenance console, this terminal is actually fitted on the B disc, where the fault details can be stored. The switching control processor passes all relevant information to the disc handler processors to make this approach possible.

Disc Handler Processor

The disc handler processor has a 40 Mbyte Winchester disc and a 20 Mbyte 0·25 in streaming-tape cartridge. The present production machines run satisfactorily under the CP/M operating system, but in particularly demanding applications a more advanced operating system on a mini-computer would be used.

The 5 main disc files used by the system are as follows:

(*a*) *Key File* This contains the details of each key page on the system, each layout requiring a 1 Kbyte record using a numeric access key.

(*b*) *Line File* This contains the items required to define each line on the system. Each line requires one 128 byte record and has various usage groups, signalling specifications etc.

(*c*) *Dial File* This has one 128 byte record for each entry in the short-code list. The actual number to be dialled is followed by a remark which appears on the screen status line while dialling is taking place.

(*d*) *Data File* This is divided into 2 Kbyte records keyed numerically. Each record is a page of 24 lines by 80 characters. The pages can be created at a user's terminal and saved into the file.

(*e*) *Index File* This is an index of the data files and contains the top lines of each data file including the creation date and time to enable the rapid generation of a partial index of the data file by a user.

There are 2 disc handler processors, both of which have the same address. Arriving commands to save or modify data on the discs are actioned by both processors to ensure that the files are always identical on both handlers. Arriving commands to retrieve information are dealt with only by disc A. Disc B is enabled for retrieval only if it is discovered that disc A is faulty. Under such fault conditions, all save and modify activities are prohibited to prevent the discs getting out of step.

The condition of the disc handler processors is continuously monitored by the system assurance functions of the switching control processor.

As the work load of disc handler processor B is very small, it is a suitable point to log faults and trace information to disc and to connect the maintenance console.

Athough the disc handler processors are duplicated, it is still necessary to make occasional dumps of the discs for disaster recovery. The 0·25 in tape drive is provided for this purpose.

Terminal Cluster Processor

The terminal cluster processor generates the video signal for a group of 8 independant screens. Each screen has its own memory-mapped video generator. The pictures can be changed very rapidly (3 ms) without flicker.

Incoming key pages fetched from the disc are used to generate new key images. Minor line-condition changes require inspection of each of the 8 video images in turn. If the line concerned exists on any screen, the video image is adjusted to match the new line status.

The video generator hardware has a fully programmable line and frame rate as well as a programmable character set. Invisible refresh gives high-speed operation without errors in the display.

A 4800 baud data link connects all the terminals in the cluster. Each terminal is asked in turn for data and either responds NAK (no data), or gives the value of the key operated or the ASCII code from the keyboard.

One special mode of operation gives access to the V24 ports. A terminal user lists a specific key to attach himself to one of 8 ports on the cluster. The top 24 lines of the screen are cleared, and thereafter anything entered by the user is sent out to the attached port. Consequently, any data arriving from the outside world at the V24 port are displayed on the attached user's screen. A limited number of more advanced facilities are offered, including clear, cursor move and direct cursor control. This V24 facility allows the user to access external computer hardware, perhaps via protocol converters, Telex, message switching exchanges and local area networks. The use of the new Teletex facilities will be straightforward.

CALL QUEUING

The system can display only 64 keys at a time, but users can have as many as 500 lines terminating. To enable the user to be aware of all incoming calls on the system, one or more unused keys are left on the display. These are collected into a group and used to display the key labels for incoming calls. All the user has to do is touch the key as it appears to select the line. Once selected it disappears from all the other screens except the successful position now talking on the line.

Typically, 3 or 4 uncommitted keys can be set up on a screen, but often there are more than 4 incoming calls at a time. The group is then used as a cyclic queue showing the latest incoming calls and pushing out the oldest call as a new one arrives. This is different to normal ACD systems, which require calls to be dealt with in strict turn. In foreign-exchange dealing, it is common for particular lines to be deliberately neglected when trading is busy. To ensure that incoming calls are not lost completely, an unanswered call is re-advised to the queues after 30 s.

By slightly modifying the queuing algorithms, it is easy to use the system in a traditional ACD application, but with the added advantage of integral computer access facilities.

DATA MANAGEMENT

Management of the 5 main data files for a large system requires some care. For example, the design of key pages must take into account the possibility of getting stuck with a key page on display with no keys programmed to change to another page.

The data files can be updated at the maintenance console by a program on disc B operating off-line. The initial generation of the customer's files is often done this way. A more elegant method involves using the data-file editing facility at the console. Special proformas exist on the system data file to enable key layouts, line definitions and short codes to be altered. The required proforma is recalled, the page is renumbered to a spare page and the relevant facts are entered at the keyboard. For example, to modify a key on a particular page, it is necessary to enter the key-page number, the key number, the function to be effected by the key, the data associated with the function (for example,the line number in the case of line select), and the label to be displayed at the key. Once all the edits are stored on the form, it is saved in the data file. The data file can then be submitted simultaneously as a batch operation to both disc handler processors, which read the proforma, vet it, and perform the requested updates. The user is informed of the completion of the operation. This work can be done by the user while the system is running.

Paper copies of the main files are useful to have, and users can return their dump tapes to BT, which will supply listings in various formats to aid management of the data.

THE FUTURE

The City Business System is unique, and diverse applications for it are being put forward around the world. Apart from meeting a vital need in London's business community, it is expected that very substantial international sales will be achieved.

The software design is such that new facilities can easily be added, and the author would be pleased to receive any proposals on interfacing the system to special telephony or data services.

The London Overlay Network

E. W. PENN†

UDC 621.394.4: 621.395.74: 621.395.2

This article describes the London Overlay network, a digital network that has been established to enable private circuits to be provided quickly for business customers.

INTRODUCTION

The London Overlay network, which was introduced in 1981, is now seen as an important milestone in British Telecom London's (BTL's) drive to offer more reliable communications services to the capital's businessmen in much shorter lead times. It is a digital network which literally overlaps other telecommunications services, and provides transmission facilities separate from BTL's main network.

NETWORK

The London Overlay network was based on the use of spare digital line sections already existing in the junction network, together with 30-channel first-generation pulse-code modulation (PCM) multiplexors (MUXs).

The network originally included 9 central London telephone exchanges with Baynard House at the hub of the network. These 9 exchanges were Bishopsgate, Faraday, Holborn, Moorgate, Wood Street, Clerkenwell, Fleet Street, Monument and Wapping. It was originally intended that only customers on these exchanges would be connected to

† British Telecom London

the network, but the network has since been extended to include customers in Croydon, Paddington, Marylebone, Sunbury, Covent Garden, Watford and Colindale. Approximately 800 circuits are at present in service on the network.

Initially, 5 digital bearers were set up to each of the 9 exchanges, and a suite of 35 MUXs was installed in Baynard House for cross-connecting purposes. Five digital bearers were provided to the London Telecom Tower to supplement the initial provision by the use of 19 GHz digital radio. The radio equipment has been used to bring customers in the outer London areas onto the network.

CIRCUIT PROVISION

A special London Overlay Circuit Provision Group was set up in BTL to deal with customer demand. The targets for the provisioning times for PCM systems and circuits are as follows:

Systems

30 or 6 channels	4 weeks

Circuits

Overlay to Overlay customer	24 hours
Overlay customer to non-Overlay customer within BTL	10 days
Overlay customer to non-Overlay customer outside BTL	6 weeks

So far, the average provisioning times that have been achieved are within these targets, and the best provisioning time for a circuit has been 3 hours from when the customer's order was received.

CUSTOMER EQUIPMENT

The installation at the customers' premises consists of the PCM MUX, ringing converters and test access equipment fitted in a customer data cabinet (Rack Apparatus No. 73B/1). Fig. 1 shows a typical rack layout. Space is left available for the provision of a 19 GHz digital-radio supervisory panel and stand-by power supply batteries if required. Power for the MUX can be obtained from the customer's PABX supply or a separate mains-derived supply. This can be provided either by a Rectifier No. 152A/10 with stand-by batteries, or Power Unit No. 78A without stand-by batteries, alternatively a Rectifier No. 152B/10 may be used with or without stand-by batteries.

When the network was first set up, Signalling Card PCM No. F5A for single commutated DC (SCDC) signalling was not available, and thus for private circuits the first-generation PCM equipment was limited to in-band signalling. To overcome this, and in order to accommodate manual signalling, several Overlay signalling conversion racks were constructed. These consisted of Signalling Units No. 27A, matching transformers, terminating units and flexibility terminations, contained in a Rack Apparatus No. 73B/1. This allowed the following manual signalling methods to be provided:

(*a*) balanced battery bothways;
(*b*) 25 Hz bothways;
(*c*) B-wire earth in, 25 Hz out;
(*d*) B-wire earth in, reversal out;
(*e*) 25 Hz in, loop out; and
(*f*) loop in, 25 Hz out.

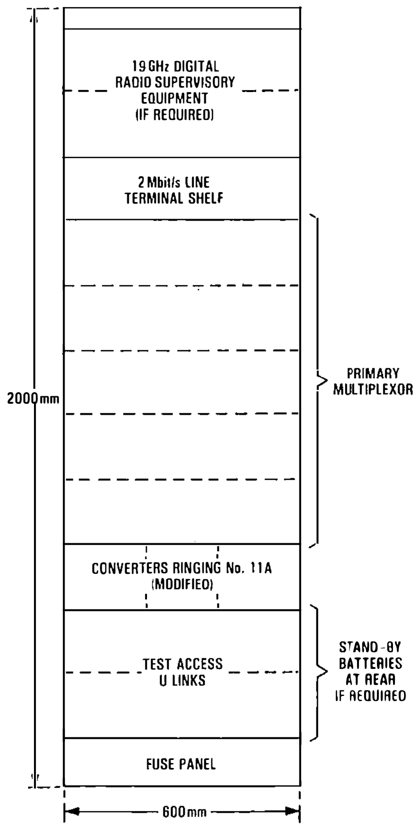


FIG. 1—Typical rack layout for a customer's installation.

The provision of these signalling facilities was essential to enable various specialised systems operating in the City of London to be connected to the network.

It was considered that the provision of this second rack in a customer's premises (assuming that a MUX rack had already been installed) was to be only a temporary expedient. The answer was to have a PCM signalling card designed to cater for the required manual signalling facilities. In addition, the provision for external extensions and out-of-area exchange lines was also required. GEC Telecommunications Ltd. was approached with a view to having the necessary PCM signalling cards designed.

Suitable designs were available as off-the-shelf items for the external extension and out-of-area exchange line (loop calling only) requirements; and a signalling card for manual signalling was specially designed to include matching transformers, terminating units and adjustable gain from −3 to +10 dB. These signalling cards are now available, and the temporary signalling racks will eventually be recovered.

As an alternative to 30-channel systems, customers can be supplied with 6-channel systems on the Overlay network. The 6 channels are derived from a pre-provided MUX situated in the customer's serving exchange, and the customer's service is fed over normal local cable pairs, 2 pairs being allowed for each circuit.

ACKNOWLEDGEMENT

The author would like to thank all those staff who have met the challenge of the completion targets to enable the London Overlay network to be a success.

Optical-Fibre Transmission Systems in the British Telecom Network: System Design

A. W. MUIR, B.SC.(ENG.), C.ENG., M.I.E.E.†

UDC 621.391.63 : 621.395.4

This article describes aspects of the optical-fibre systems that will be installed under British Telecom's 'standardised systems' programme. It describes the basic designs, performance parameters and maintenance facilities of these systems, and goes on to consider the developments in optical-fibre systems that are likely to take place in the future as a result of rapid advances in technology.

INTRODUCTION

An earlier article in this *Journal*[1] presented an overview of British Telecom's (BT's) plans for the introduction of optical-fibre transmission systems, and indicated that by the end of the 1980s at least 50% of the main network, together with a substantial proportion of junction routes, will consist of monomode or multimode optical-fibre systems. The majority of these systems will be installed under the 'standardised systems' programme, which is based on the principle of rationalising designs at 34 Mbit/s and above to 3 basic configurations, the key parameters of which are shown in Table 1.

The success of BT's rapid optical-fibre implementation programme will be strongly dependent on achieving system designs which enable the technological and economic advantages of optical transmission to be fully exploited, but which at the same time recognise the operational practices that have evolved over many years in the BT cable network. The designs adopted for the standardised systems are described in this article.

BASIC SYSTEM DESIGN

The basic arrangement of an optical-fibre line system closely resembles that of the coaxial cable systems which have been operated in the BT network for some years now[2]. The similarity extends to the general configuration of terminal and regenerator equipment (Figs. 1 and 2), but more detailed consideration of the system design reveals a number of differences in the implementation of the 2 technologies. These differences are highlighted throughout this article, but perhaps of most significance is the considerable increase that can be achieved in regenerator spacings. Indeed, the characteristics of the BT duct network are such that, with the regenerator spacings shown in Table 1, no dependent (underground) regenerators will be required for the 34 Mbit/s junction or the monomode main-network systems.

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TABLE 1
Standardised System Design Parameters

Type	Network Application	Maximum Regenerator Spacing	Power Feeding
34 Mbit/s	Junction (Short haul)	10–15 km	None; no underground repeaters
140 Mbit/s (Multimode)	Main (Long haul)	10 km	± 100 V DC
140 Mbit/s (Monomode)	Main (Long haul)	30 km	None; no underground repeaters

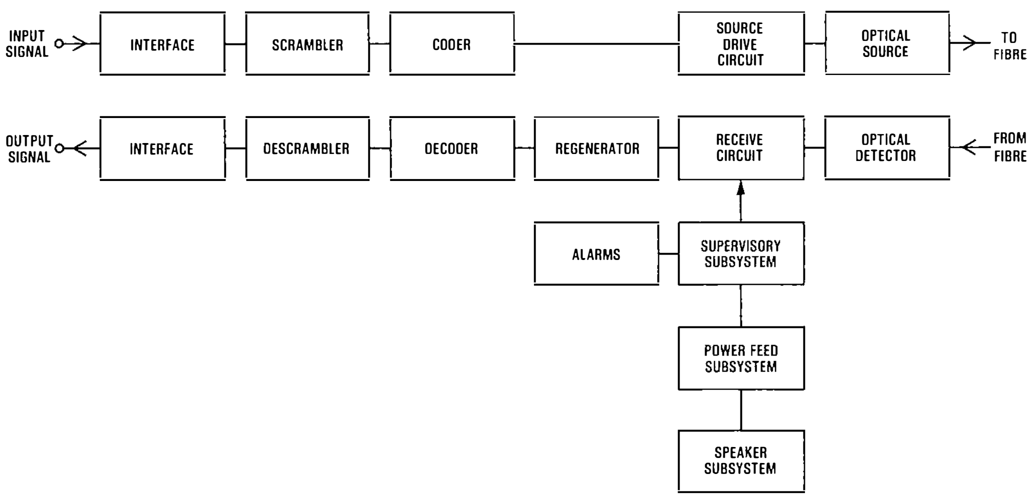


FIG. 1—Configuration of terminal equipment for an optical-fibre transmission system

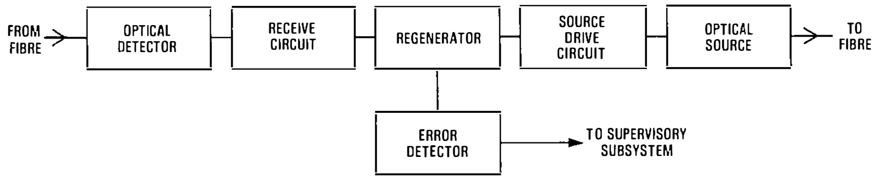


FIG. 2—Configuration of regenerator equipment for an optical-fibre transmission system

Reference to Fig. 1 shows that the terminal equipment is made up from the following building blocks.

Transmit Terminal Equipment

Line Coder and Scrambler

One of the principal functions of the transmit terminal equipment is to translate the input signal into a format suitable for transmission along the optical fibre. This translation is carried out in the scrambler and coder by means of a line code which should introduce the following properties, regardless of the structure of the input signal:

(*a*) limited power at low frequencies,
(*b*) limited power at high frequencies,
(*c*) a suitable pulse sequence for the derivation of a timing signal at the receive terminal,
(*d*) a suitable pulse sequence for maintaining circuits with automatic gain control at the correct level,
(*e*) ease of translation between the input signal and line code, and
(*f*) some means of providing in-service performance monitoring.

Line codes for coaxial systems are generally based on the principle of converting the incoming binary signal into a 3-level (ternary) signal, (that is, positive, negative and zero pulses) in order to limit the transmitted power at both high and low frequencies; typical examples are 4B3T (4 binary, 3 ternary) for 120 Mbit/s systems and 6B4T for 140 Mbit/s systems. Ternary codes are, however, unsuitable for optical systems which can basically transmit only 2 conditions (that is, the absence or presence of light) along a fibre, and hence a balanced-disparity binary line code of the form nB(n+1)B is generally adopted. In this code, a block of (n) traffic bits (usually 5 or 7) is converted in the transmit terminal to a block of (n+1) bits (that is, 6 or 8), with the added bit being chosen in accordance with a conversion table that optimises the above requirements.

Optical Source

The encoded line signal is used to modulate directly the opto-electronic source device. The sources used for the standardised systems have been briefly described in reference 1 but, for convenience, the main characteristics are given in Table 2. The laser diode provides a higher output power together with a good launch efficiency and reduced spectral linewidth, and is particularly suited to monomode systems. On the other hand, light-emitting diodes (LEDs), although emitting less optical power than lasers and having considerably wider spectral linewidths, are generally cheaper and easier to utilise, as they require less sophisticated drive circuitry.

The overall design philosophy of the transmitter module is largely determined by the optical-power/drive-current characteristic of the source. In the case of the LED, this may simply involve switching the device by the encoded line signal between zero, or a near-zero, current and a preset maximum. The same technique cannot be applied to lasers because the variation of threshold current with temperature requires the provision of a feedback loop. In addition, it is desirable to switch the laser from a point usually just below the threshold, so as to minimise switch-on delay and other secondary effects such as transient spectral broadening. Laser systems usually, therefore, incorporate feedback control whereby optical power from the back facet is monitored by a photodiode. The feedback current from this photodiode is used to ensure that the laser is operated within its defined design limits. When the laser is operated from a point close to the threshold, a small amount of light is emitted when a logic 0 is being transmitted. This small amount of optical power as a percentage of the optical power transmitted during a logic 1 is known as the *extinction ratio* and must be allowed for in the overall system design.

The matching of the optical source with the fibre is a critical aspect of the overall system design. Not only must the operating wavelength and linewidth of the source be compatible with the transmission window of the fibre, but the launch conditions must also be controlled to minimise potential problems such as mode partition noise and the effects of reflected optical power at the fibre joints. These subjects are beyond the scope of this article, but are well documented elsewhere[3].

TABLE 2
Summary of Typical 1300 nm Source Device Performance

Device	Material	Typical Output Power Coupled into Multimode Fibre	Typical Modulated Linewidth (nm)
Laser	InGaAsP	0·5–2 mW	8
Edge-Emitting LED	InGaAsP	0·1–1 mW	70
LED	InGaAsP	0·05–0·2 mW	110

Receive Terminal Equipment

Optical Detectors

The PINFET detector adopted for standardised systems has also been described in reference 1, and the improvements in sensitivity levels over germanium avalanche photodiodes at the operating wavelength of 1300 nm have been emphasised.

This sensitivity is achieved by combining the PIN photodiode chip with a field-effect transistor (FET) chip on the same substrate, thereby minimising stray capacitances. The PINFET combination can be realised in 2 different ways: firstly, through a high-impedance design in which the photodiode load resistance is made high such that its terminal noise contribution is negligible (and hence the receiver response is dominated by the input capacitance); or secondly, through the use of a transimpedance receiver design in which the photodiode drives a lower-input-impedance feedback amplifier.

Line Decoder

The prime function of the decoder is to translate each block of $(n+1)$ bits of the line code back to the original block of (n) traffic bits in accordance with a conversion table complementary to the one in the coder. In addition, the decoder provides a system error monitor by detecting violations of the coding algorithm in the received line signal. These violations are flagged to an error monitor which assesses the aggregate system error rate and which, in turn, activates the appropriate supervisory and alarm conditions.

Repeater Equipment

Comparison of Figs. 1 and 2 shows that an intermediate regenerator essentially consists of a receive and transmit terminal (without the line coder and decoder) connected back-to-back. A basic error monitoring facility is provided by inspecting the line code in the regenerator, and line power feeding and supervisory facilities are connected where required.

OPTICAL CABLE SECTION PARAMETERS

As with a coaxial line system, the fundamental transmission parameters of an installed optical-fibre cable section are the attenuation and bandwidth. In the case of a coaxial line system, these parameters can be readily calculated from basic transmission theory, and it is possible to manufacture cables whose characteristics are in close agreement with theoretical predictions. A very different situation applies to optical-fibre systems, where a number of ambiguities can be experienced in the definition and measurement of the basic characteristics. The values adopted for the BT standardised systems are shown in Table 3, and the interpretation of these values is now discussed.

Attenuation

Optical attenuation is defined as the decrease of average optical power between 2 points, and results from absorption, scattering and other radiation of light in a fibre and any joints. A typical fibre attenuation characteristic is shown in Fig. 3, where it can be seen that fibre loss is a function of the operating wavelength. The loss is also dependent on the distribution of modes in the fibre as a result of the effects of scattering and radiation.

In specifying and measuring the loss of a fibre, it is therefore necessary to define the wavelength of operation and mode distribution, and it can be seen from Table 3 that a wavelength window ranging from 1275 nm to 1325 nm has been adopted by BT. Within this window, the attenuation has been specified on a uniform basis, although in practice the effects of absorption and scattering could introduce a variation of up to 2 dB across the wavelength range.

The distribution of modes in the fibre is very much a function of the launch conditions, and it is thus particularly important to define these conditions when attenuation characteristics are being specified and measured. This is reviewed later in this article.

TABLE 3
Characteristics of Installed Repeater Sections

System Type	Attenuation	3 dB Modal Bandwidth
34 Mbit/s	22 dB	40 MHz
140 Mbit/s (Multimode)	17 dB	140 MHz
140 Mbit/s (Monomode)	23 dB	(not specified)

Note: All values apply across the wavelength range 1275–1325 nm

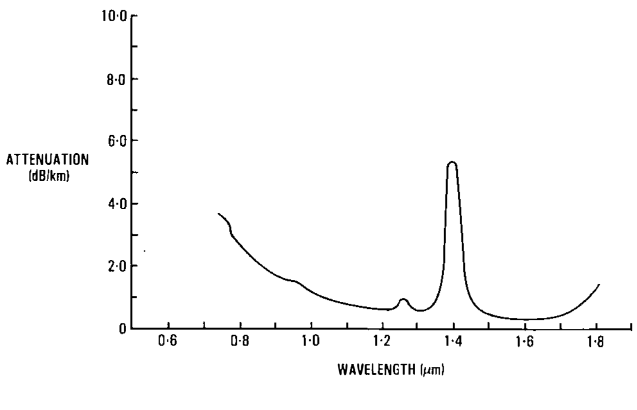


FIG. 3—Typical fibre attenuation characteristic

Bandwidth

The concept of bandwidth has traditionally been applied to line transmission systems and in the case of optical fibres has been defined as the 'lowest frequency at which the magnitude of the fibre transfer function decreases to a specified fraction of the zero frequency value. Often the specified value is one half the optical power at the zero frequency.' In a multimode fibre system, the resultant bandwidth is primarily influenced by the relative delays of the different modes which are propagated along the fibre, and the overall effect is to degrade the eye at the receive terminal. However, the relationship between the measured bandwidth and eye degradation is complex, and indeed the general concept of bandwidth in optical-fibre systems is still a subject of considerable debate.

One significant aspect of this debate is the manner in which the bandwidth of individual multimode fibre lengths add together over an installed regenerator section. This addition (generally known as *concatenation*) is usually modelled as a power law which, in its simplest form of a regenerator section consisting of n individual lengths of fibre each having a modal bandwidth of B, takes the form:

$$\text{total bandwidth} = Bn^{-\gamma},$$

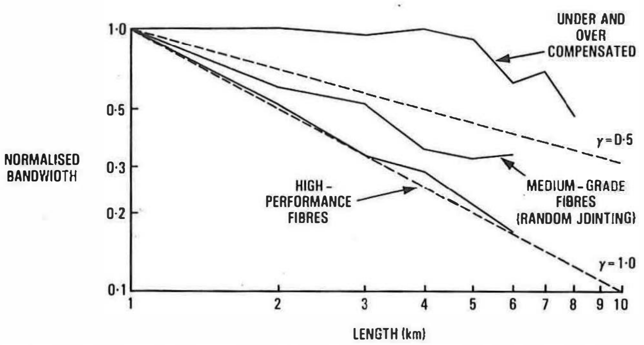
where γ generally lies in the range of 0·6 to 1·0. The concatenation of a range of different fibres is shown in Fig. 4, where it can be seen that a universal choice of γ is at present impracticable.

Despite the difficulties of applying the concept of bandwidth to optical fibres, it is nevertheless necessary to specify overall system objectives, such as those in Table 3. As with attenuation, the bandwidth values for the BT standardised systems have been defined over the wavelength range 1275–1325 nm.

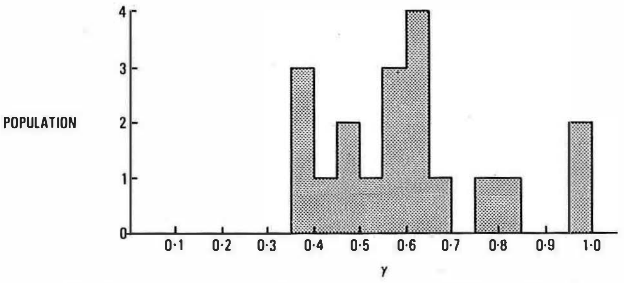
SYSTEM MARGINS AND BUDGETS

In designing a practical system, it is necessary to combine the characteristics of the terminal and regenerator equipment with those of the optical-fibre cable in such a way that adequate margins are incorporated for effects such as temperature variations and performance degradations experienced over the system lifetime. These characteristics are expressed in terms of attenuation penalties and are combined in a system budget of the form shown in Table 4 for a 140 Mbit/s monomode system. It should be noted that this budget includes an allowance of 2 dB for the maintenance and/or diversion of the installed cable during its operational life. This allowance is about 10% of the loss of the elementary cable section and has been assessed from experience of the maintenance requirements of the BT external plant network.

One of the key factors that influences the system budget is the required spacing between successive regenerators. The maximum spacings adopted for the BT standardised systems



(*a*) Examples of the bandwidth addition of concatenated fibre lengths (based on a sample of 19 jointed links)



(*b*) Histogram showing distribution of γ (sample of 19 jointed links)

FIG. 4—Fibre concatenation

TABLE 4
Typical System Budget Calculation for a 140 Mbit/s Monomode System

1	Available power ratio (transmitter output — receiver threshold level)	36 dB
2	Regenerator section cable loss (Table 3)	23 dB
3	Connector and cable termination losses	4 dB
4	Maintenance margin	2 dB
5	Variation of electro-optical device and other component performance with temperature and time	3 dB
6	Circuit realisation penalty	4 dB
7	Total—Items 2–6	36 dB

(Table 1) have been determined from consideration of the structure of the existing duct network, and require the use of fibre with relatively high performance characteristics to meet the requirements of the system budgets. Inevitably, a number of regenerator section lengths considerably shorter than the maximum will be experienced in a practical network, and fibres with a lower performance characteristic can be used over these shorter lengths within the constraints of the system budgets. In order to optimise the mix of fibre qualities and hence minimise costs, the principle of prescriptive routeing is currently being used to design regenerator sections of the BT standardised 140 Mbit/s systems. Under this principle, each individual regenerator section is designed to meet the performance requirements of Table 3, irrespective of length, and an appropriate fibre quality is selected which is compatible with this performance requirement.

SUPERVISORY AND SPEAKER FACILITIES

Fig. 1 shows that, in a practical line system, the traffic path is augmented by ancillary facilities such as supervisory and speaker subsystems. The introduction of optical-fibre cables has necessitated a modification of the traditional philosophy of providing these subsystems, primarily as a result of the reduction in the number of available copper conductors in the cables.

Coaxial cables generally have contained an adequate number of auxiliary pairs to provide one speaker circuit per line system, together with a telemetry path capable of conveying comprehensive supervisory information. Furthermore, the location of regenerators at spacings of a few kilometres has enabled equalisation and amplification of the audio path to be carried out.

Design and manufacturing constraints of optical-fibre cables tend to limit the number of auxiliary copper conductors which can be used for supervisory and speaker purposes. Firstly, there is a limit to the number of elements (fibre or copper) that can be accommodated in a single layer of a cable construction; and secondly, the overall weight of the cable must be maintained at a level that enables practicable lengths of cable (2 km or more) to be installed without undue strain being transferred to the fibres. Thirdly, the conductors are laid up in a well-structured format which, together with the long intervals between successive joints, tends to result in performance levels of the auxiliary conductors, particularly crosstalk, which are approaching the limits of acceptability.

The design of optical-fibre cables will be discussed in detail in a subsequent article in the *Journal*, and, for the present, only the implications of the auxiliary-pair characteristics on the overall system design will be considered. The 2 principal implications are:

(*a*) only a limited provision of speaker circuits within a single cable sheath will be possible, and

(*b*) supervisory information should, if possible, be conveyed along the cable by means other than copper conductors.

Speaker Circuits

The need for a speaker facility on an optical-fibre system has been reviewed in detail, and it was concluded that an order wire for equipment maintenance purposes could be eliminated from systems with no underground plant. However, it was recognised that a speaker facility was of considerable benefit to jointing operations, particularly on the monomode routes where terminal or regenerator equipment could be spaced apart at distances of up to 30 km. For this reason, it was decided to provide at least one audio speaker circuit on copper conductors within each cable sheath.

Supervisory Facilities

Research and development activity within BT[4] has demonstrated that a limited amount of auxiliary information can be transmitted along an optical line system by additional modulation of the light sources. This technique, akin to supermodulation of radio-relay systems and shown diagrammatically in Fig. 5, will be incorporated on the BT standardised 140 Mbit/s optical-fibre systems to convey supervisory information from intermediate regenerators to the system terminals. By using optical transmission techniques, the need for additional copper pairs to convey supervisory information is eliminated.

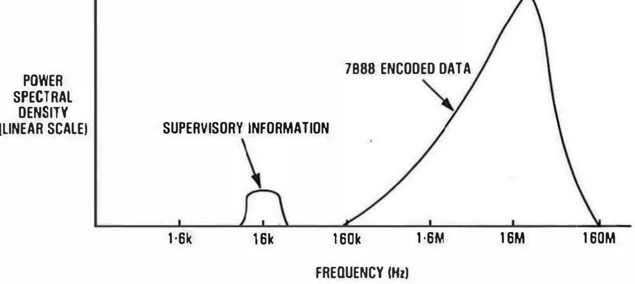


FIG. 5—Optical supervisory

MEASUREMENT TECHNIQUES AND TEST EQUIPMENT

The ambiguities in defining concepts such as optical attenuation and bandwidth, discussed above, are reflected in the measurement techniques and equipment that have been devised for use with optical-fibre transmission systems.

One of the principal difficulties to be overcome in optical measurements is their accuracy and reproducibility. The measured parameters of optical fibres can depend on many factors, such as the launch excitation, the measurement of absolute optical power, interference from ambient light and inconsistencies in optical connectors. To minimise these uncertainties, international recommendations, such as those of the CCITT†, will be based on reference test methods (RTMs) that are intended to yield accurate and reproducible results which can provide a common reference point. Unfortunately, some RTMs are expensive and time consuming, and may be suitable for use only in a controlled environment such as a test laboratory. Under these circumstances, alternative test methods are used for factory and field applications.

The scope of this article is limited to a brief discussion of the field test equipment and methods to be adopted for the BT standardised systems; reference should be made to other papers[5] for a discussion of the RTMs.

Attenuation

The dependance of an attenuation measurement on the optical launch conditions can be minimised by adopting a technique known as the *cut-back* method. The output power from the full length of fibre is measured and then, without changing the fibre input conditions, the fibre is cut back to a point some 2 m from the launch end, and the output power from the short length is measured. Although this technique provides an accurate and repeatable means of measurement, it is evidently a destructive method and cannot be applied, for example, to a fibre length terminated at each end by connectors. It also requires the transportation of test equipment between the 2 ends of the fibre, which may be up to 30 km apart. An alternative approach is to adopt a *pseudo-cut-back* method where the launch conditions are controlled as accurately as possible. This approach, which is used in field attenuation measuring equipment such as that shown in Fig. 6, gives results that are repeatable to about 1 dB.

FIG. 6—Field attenuation measuring set

FIG. 7—Optical time-domain reflectometer

Bandwidth

There are 2 approaches to the measurement of bandwidth: in the time domain or in the frequency domain. The preferred approach within BT is to measure the fibre impulse response in the time domain, and to compute the bandwidth response by means of a Fourier transform. The measurement is highly dependent on the fibre launch conditions and the linearity of the detector, and, consequently, great care is required to ensure good reproducibility of bandwidth measurements. For this reason, and because of the difficulty of implementing a remote-ended time-domain measurement, bandwidth measuring techniques tend currently to be restricted to the laboratory or factory, rather than the field.

Fault Location

A useful instrument that can readily be used under field conditions to provide an overall indication of fibre quality, and in particular fault location, is the optical time-domain reflectometer(OTDR). This equipment (Fig. 7) launches a pulse into the fibre, and displays the light reflected as a trace on a cathode-ray tube (CRT). The reflections result from either discontinuities in the fibre (for example, breaks, joints or an unmatched fibre end) or from Rayleigh scattering along the length of the fibre. This back-scattering effect is displayed as a logarithmic trace on the CRT, and any fibre discontinuities appear as discrete vertical steps. The location of a discontinuity can then be assessed from the position of the step on the X-axis of the CRT and the magnitude from the height of the step. Hence, for example, the location of a fibre break or the magnitude of a joint loss can be readily assessed.

FUTURE TRENDS

The parameters adopted for the BT standardised system programme (Table 1) have been based on optical-systems technology that is currently available for production engineering. The present rate of technological advance is, however, so rapid that the transmission of higher capacities over

† CCITT—International Telegraph and Telephone Consultative Committee

longer regenerator spacings will be practicable in the very near future.

Higher Capacities

The introduction of monomode fibre, which has a very high usable bandwidth, opens up the prospect of operating systems at rates in excess of 140 Mbit/s. The 2 principal constraints to higher-rate operation are the ability of the electronic and opto-electronic modules to function at the high line rates, and a decrease in the receiver sensitivity of about 5 dB for each doubling of the line rate. This decrease in sensitivity can be offset by higher transmit powers, or improved receiver design, and technology has already advanced to the stage where transmission of 2×140 Mbit/s (that is, an encoded line signal rate of about 320 Mbit/s) is completely feasible and where 4×140 Mbit/s (that is, a line rate of about 650 Mbit/s) is rapidly becoming practicable.

Multimode fibre cannot be exploited so readily at higher line rates, because of the inherent bandwidth limitations of the fibre. Some increase in transmission capacity can, however, be achieved by using partial response coding techniques. These techniques, comparable to those which have been developed for BT's 140 Mbit/s digital radio-relay systems[6], allow the received eye to be degraded in a controlled manner by the bandwidth-limited transmission path, and then re-create a detectable eye at the regenerator through the use of decision feedback circuitry. The penalty of introducing such techniques is, again, reduced receiver sensitivity, but as with the higher-bit-rate systems this can be offset by either higher transmit powers or improved receiver design.

Wavelength-division multiplexing techniques, whereby a number of independent signals are transmitted along a fibre at different operating wavelengths, offer an attractive means of increasing the capacity of a fibre with little increase in complexity. The multiplexing can be organised either on the basis of nominating 2 wavelengths within the same operating window (for example, at about 1300 nm) or by working in 2 separate windows (for example, 1300 nm and 1500 nm).

Multiplexing within one window has the disadvantage of introducing relatively stringent limits on the wavelength-related characteristics of both the fibre and opto-electronic devices, and may not prove to be cost effective with current production technology. The second alternative is also dependent on well-structured fibre characteristics, in this case requiring the transmission characteristics to be optimised in 2 different windows. This is particularly difficult for high-capacity systems on multimode fibre where the modal dispersion (and hence bandwidth) can be optimised only at one wavelength.

Increased Repeater Spacing

The system designs discussed so far in this article have been based on the principle of direct detection, whereby the amplitude of the transmitted light is detected at the optical receiver, and hence the sensitivity is primarily limited by thermal noise. Increased sensitivities of 10 dB or more can be achieved through the use of coherent transmission techniques using homodyne or heterodyne detection[7].

An example of the achievable improvement in sensitivity, based on work at British Telecom Research Laboratories, is shown in Fig. 8. It should, of course, be noted that the increased sensitivity of some 10 dB would allow the addition of some 10–15 km of spliced monomode fibre in each regenerator section.

CONCLUSION

Optical-fibre technology has now matured to the point where systems are being installed in the BT network on a routine basis and where the necessary operational back-up in areas such as test equipment is becoming well established. It is anticipated that the basic design concepts reviewed in this article will continue to be applied to systems for several years to come, but that further advances in technology and increasing operational demands may well result in systems with higher traffic capacities and larger regenerator spacings in the not too distant future.

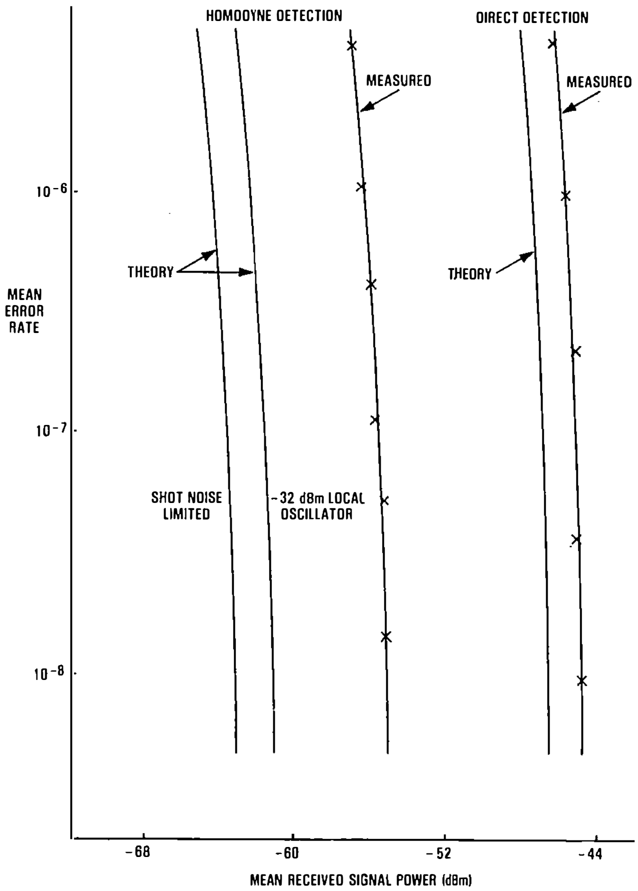


FIG. 8—Improvements in receiver sensitivity (140 Mbit/s)

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Modern DC Power Systems: The Power Equipment Rack

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UDC 621.311.4–214 : 621.395.722

This article describes the power equipment rack, which is installed en-suite with standard equipment racks to provide the primary and stand-by DC power for System X.

INTRODUCTION

For many years, DC power was provided at telecommunications centres by large centralised power plants[1], comprising rectifier cubicles, switching cubicles and large stand-by batteries. In 1970, a modular power plant[2] was introduced which, although still retaining relatively large physical dimensions, had 2 advantages: it provided DC power at load centres within an exchange complex, and it could be installed to meet growing load demands, which enabled capital investment to be deferred.

When digital switching systems were introduced, the opportunity was taken to design an integrated DC power system suitable for installing alongside modern equipment practices. This has the following advantages:

(*a*) power can be provided as required and installed at the same time as switching equipment;
(*b*) power can be readily available for testing equipment either on site or at manufacturers' works;
(*c*) power planning is simplified and more flexible, with a reduction in DC distribution;
(*d*) no special power accommodation is required;
(*e*) power maintenance can be in line with equipment maintenance; and
(*f*) power is part of an exchange package, hence the export potential of System X is enhanced.

The power system that has been developed to satisfy the above criteria is completely self contained within a standard equipment-rack practice and is known as a *power equipment rack (PER)*.

CONSTRUCTION

The PER is constructed around a standard TEP1H equipment rack and, with the rack covers in place, as shown in Fig. 1, it appears aesthetically similar to any other System X equipment rack. Fig. 2 shows the equipment with the rack covers removed; the 6 shelf spaces are used to provide the following facilities:

(*a*) In the top shelf, 5 rectifiers, each rated at 1·5 kW, provide power conversion from 240 V single-phase AC to −54·5 V DC (nominal −48 V DC) to sustain a maximum load of 6 kW. Under operational conditions, all the rectifiers are energised and share the prevailing load, with one of the rectifiers providing redundant capacity of 1·5 kW to meet the required standard of reliability.
(*b*) The lower 3 shelves contain rechargeable batteries, which will provide 6 kW h of energy in the event of mains/stand-by failure.
(*c*) One of the 2 remaining shelves is utilised for a power connection panel (PCP), where DC connections from various power modules and batteries can be interconnected and fused as required. On the same shelf is a power alarm unit, where alarms from the PER can be extended and interfaced with the exchange alarm scheme. The other shelf contains provision for the termination and isolation of an incoming single- or 3-phase supply, and has fused outlet AC supplies to various modules on the rack. The remaining space on this shelf can accommodate 4 additional power modules, which can be selected to provide a secure and transient-free AC supply derived from the −48 V DC; units to provide traditional DC voltage limits of 46 V to 52 V, known as *narrow-voltage limits (NVL)*; or additional rectifiers.
(*d*) DC power is taken off at the PCP and supplied to a distribution fuse panel, from which special flexible twin cable provides power connection to individual equipment shelves.

SYSTEM PHILOSOPHY

A DC power system usually requires the following essential elements:

(*a*) a rectifier to provide DC power from an AC source; and
(*b*) a battery to provide power during a total AC failure, or power for short periods following a mains failure, until a stand-by engine alternator takes over the mains supply function.

The rectifier fulfills 2 functions: to provide the regulated voltage demanded by the equipment load, and to maintain a battery in a healthy state of charge.

For a system to be cost effective, 3 major parameters must be considered:

(*a*) The system voltage limits, which are dictated by the equipment being powered.
(*b*) The method of keeping the battery fully charged, which in the majority of cases is achieved by *floating* the battery at a constant potential across the rectifier output. In these cases, the level of the float voltage becomes important.
(*c*) The battery utilisation during the discharge period.

The system which is finally chosen becomes one that is a carefully achieved balance between the above factors.

THE PER SYSTEM DESIGN

Voltage Limits

In modern digital telecommunications switching systems, the power interface at the equipment rack is usually a DC–DC conversion stage. It is therefore feasible to operate this equipment over a much wider input voltage window

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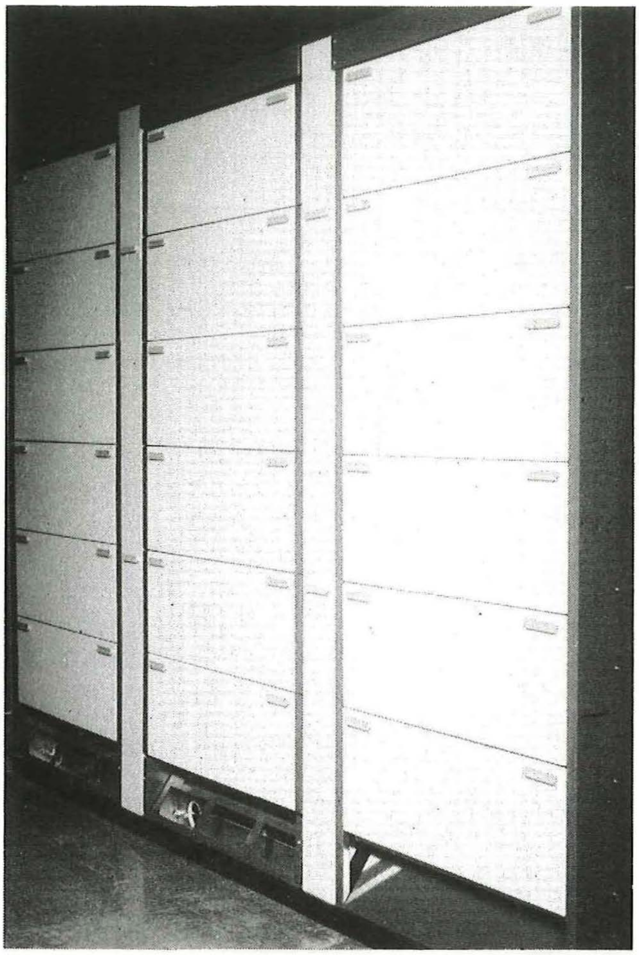


FIG. 1—Power equipment rack *en-suite* with System X equipment (covers in place)

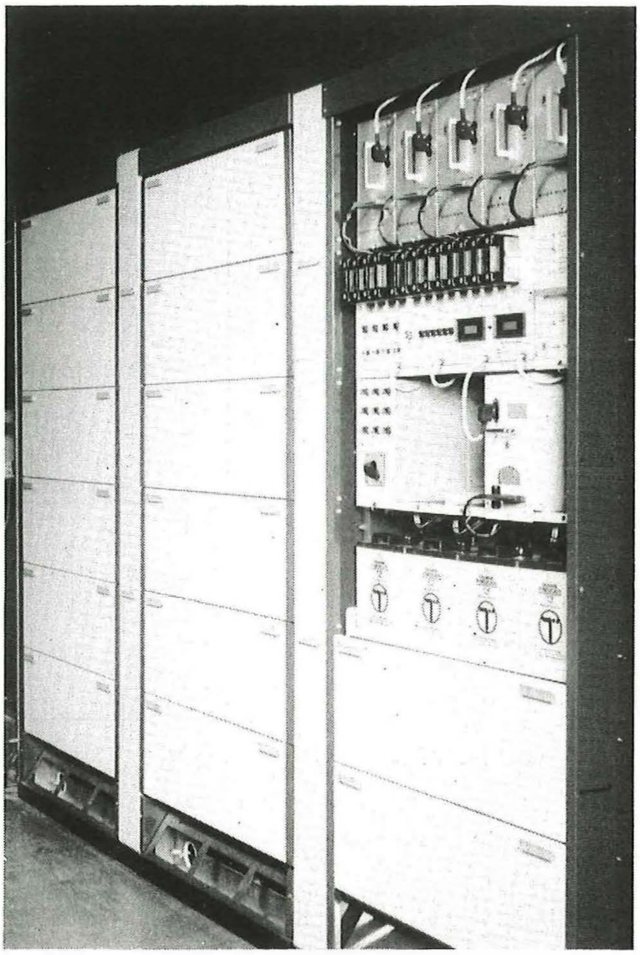


FIG. 2—Power equipment rack *en-suite* with System X equipment (covers removed)

than has traditionally been possible with electromechanical switching systems. Ultimately, a voltage tolerance of 40 V to 57 V should be achievable; for the time being, however, a limit of 44 V to 56 V is specified. Allowing for a 2 V drop in the DC distribution conductors, this equates to a voltage window at the PER of 46 V to 56 V. These voltage limits are termed the *wide voltage limits (WVL)* to distinguish them from the traditional NVL of 46 V to 52 V.

Choice of Battery Size

The stationary battery most suited to telecommunications stand-by applications is made up from a number of lead-acid cells connected in series. Such an arrangement of cells can be maintained in a healthy state of charge, without the need for periodic refresher charging, if they are floated at a constant potential equivalent to 2·27 V per cell, and if they are not allowed to discharge below 1·85 V per cell. Fig. 3 indicates the working voltage range for batteries having 23, 24 and 25 cells. It can be seen that no single arrangement satisfies the NVL and provides optimum battery utilisation. Hence, in previous power plants it has been necessary to use some form of battery terminal voltage control; for example, counter-EMF cells, series regulators, end-cell switching, etc. A major advantage in WVL equipment is that it can be served by a battery of 24 cells, and so provide the opportunity for a power system to be designed using voltage-controlled rectifiers floating a 24-cell battery.

SYSTEM DESCRIPTION

A schematic connection diagram of the PER is shown in

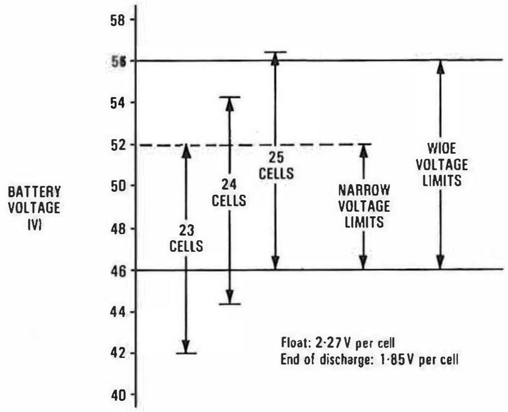


FIG. 3—Voltage limits for various sizes of battery

Fig. 4. Incoming AC power (which may be 3-phase or single-phase) is fed via an isolator and sub-circuit fuses to 5 rectifiers; the DC outputs from each rectifier are connected in parallel and fused at the PCP. Up to 3 batteries can be interconnected, via isolating links, at the PCP, which also connects them across the main DC supply from the rectifiers. The PCP also provides a DC interface connection for any other facilities that may be provided on the PER; for example, inverters or special converters. A final output connection is made from the PCP to the end-of-suite distribution connection panel, which has the capacity for 75 outgoing final sub-circuit fuses to provide power feeds to

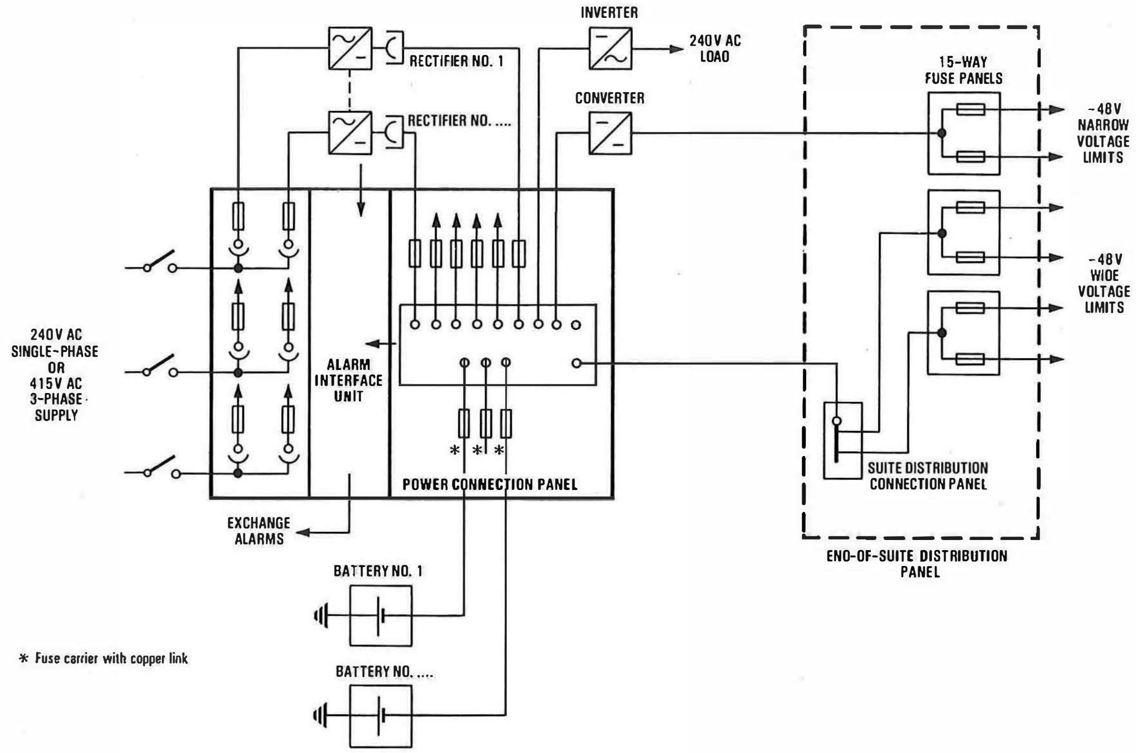


FIG. 4—Block diagram of power equipment rack

adjacent equipment racks. Each power feed has a maximum rating of 20 A, but is normally loaded to not more than 10 A.

RECTIFIERS

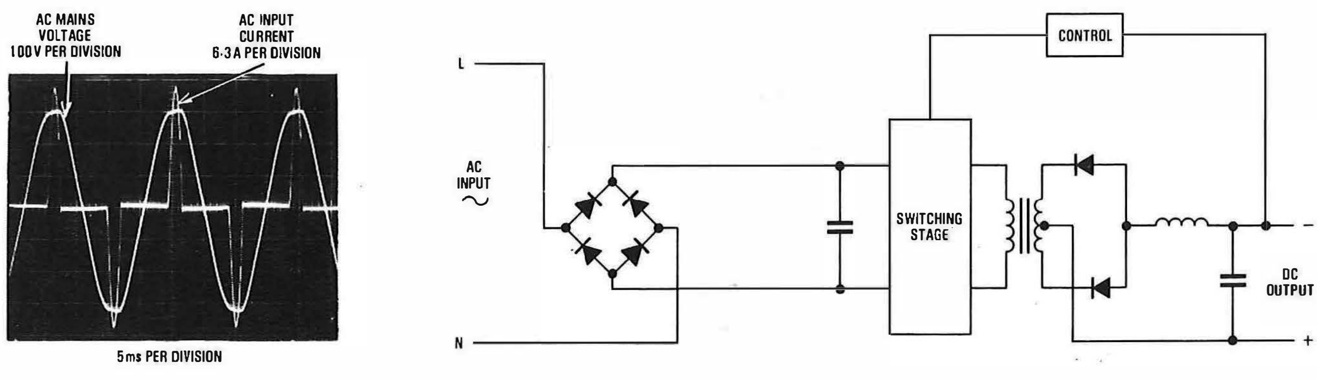
Rectifier No. 160

The design of the PER places stringent size, weight and output restrictions on the rectifiers used in the system. As a result of these restrictions, switch-mode techniques have been adopted to produce a compact lightweight rectifier called the *Rectifier No. 160.*

The Rectifier No. 160 produces an output of approximately 1·5 kW (28 A at 54·5 V), and 5 rectifiers can be mounted in the space of one TEP1H shelf. The rectifiers are sufficiently light in weight to be installed in a rack by one man. Significant reductions in size and weight in comparison with traditional rectifiers have been achieved because of the high switching frequency of switch-mode rectifiers. Fig. 5 shows in outline the main components of a typical switch-mode rectifier.

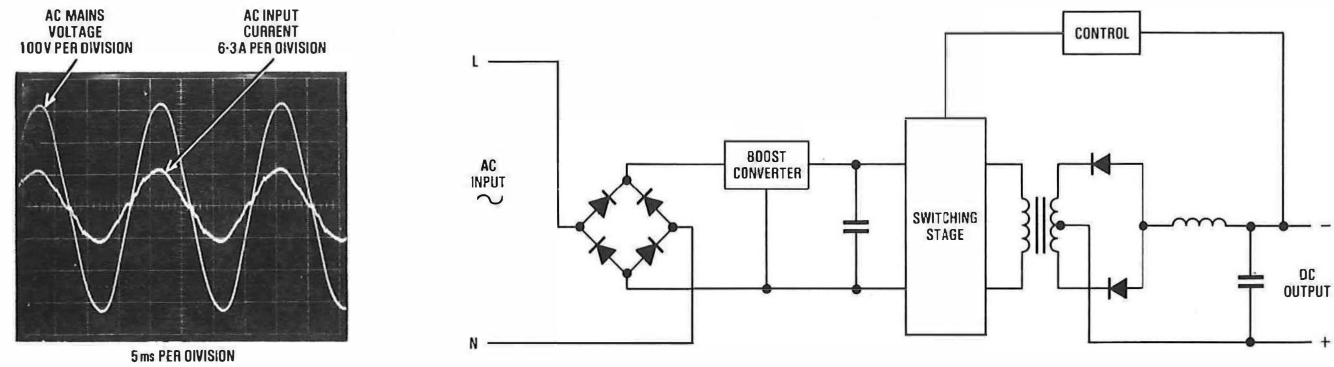
The mains supply is rectified and then smoothed by a reservoir capacitor to provide a DC bus voltage of over 300 V. This supply is then switched at a high frequency (around 20 kHz) by power transistors and fed to a transformer. The transformer steps the voltage down and provides isolation between input and output circuitry. The output from the transformer is rectified and smoothed to the required limits. Output voltage control is achieved by varying the pulse width of the switching stage.

The increase in operating frequency from mains frequency, at which traditional rectifiers operate, to 20 kHz allows considerable reductions in the size of the transformer and filter components. Bulky iron-cored components as used in mains-frequency rectifiers give way to smaller ferrite-cored components.



Note: The oscillogram shows AC input waveforms for a conventional switch-mode power supply delivering 1600 W

FIG. 5—Switch-mode power supply and typical input waveforms



Note: The oscillogram shows AC input waveforms for a Rectifier No. 160 delivering 1600 W

FIG. 6—Rectifier No. 160 and input waveforms

Rectifier No. 160 Features

The Rectifier No. 160 has a number of features which set it apart from commonly available proprietary switch-mode power supplies. These special features arise from the quantities in which the rectifiers will be used in exchanges and the requirements of the telecommunications environment in which they operate. The main features are as follows:

(*a*) sinusoidal input current waveform,
(*b*) high efficiency—90% at full load,
(*c*) output characteristics suitable for parallel operation and operation with batteries,
(*d*) output noise levels to meet British Telecom (BT) Requirements No. 2511,
(*e*) low level of radio-frequency interference and conducted electromagnetic interference,
(*f*) convection-cooled operation in ambient temperatures up to 55°C,
(*g*) silent operation, and
(*h*) high reliability—better than 20 years mean-time-between-failures (MTBF).

Input Current Waveforms

Perhaps the most unusual aspect of the Rectifier No. 160 is the virtually sinusoidal input current waveforms. A conventional switch-mode supply, as illustrated in Fig. 5, has a very poor input current waveform. The switch-mode supply can draw current from the AC supply only when the AC input voltage is higher than the voltage being stored on the reservoir capacitor. This results in narrow current pulses being drawn from the AC supply at the peak of the voltage waveform. This is illustrated in the oscillogram shown in Fig. 5, which shows the input current waveform of a conventional switch-mode supply feeding a load of 1600 W. Although the input current is only 7 A RMS, it is actually being drawn in 24 A pulses. This situation can be tolerated where switch-mode supplies are used in small numbers. However, when used as the power supply for a telephone exchange, switch-mode supplies could represent 50% or more of the total load at the site. A load with such a current waveform, rich in harmonics from the third upwards, would cause severe problems with voltage distortion of engine-generator supplies and perhaps even the mains voltage waveform. The harmonic currents drawn from the mains supply would also far exceed Electricity Board recommendations. The voltage distortion at a 13 A socket outlet caused by running a single switch-mode supply is clearly visible in the oscillogram shown in Fig. 5.

The input current waveform of the Rectifier No. 160 was specified as being sufficiently good to allow up to 30 rectifiers to be connected to each phase of the AC supply. The method used to improve the input current waveform is to introduce a *boost* converter between the input rectifying stage and the reservoir capacitor. This is illustrated in Fig. 6. The boost converter is another high-frequency switching converter (typically a flyback converter), which boosts the instantaneous voltage of the incoming supply up to that of the reservoir capacitor. The switching of the converter is modulated so that the degree of boost varies with the value of the AC supply voltage. Energy can therefore be transferred from the AC supply to the reservoir capacitor over virtually the full mains cycle, rather than in narrow 40° pulses as in the case of the conventional switch-mode supply. The input current waveform of a Rectifier No. 160 feeding a load of 1600 W is shown in the oscillogram shown in Fig. 6, which demonstrates the improved current waveform, when compared with Fig. 5.

Output Characteristics

The output characteristics of the Rectifier No. 160, illustrated in Fig. 7, are defined to meet the requirements of the PER, and for operation either with or without a battery. The features to note here are the slight droop in output voltage from no load to full load to promote stable operation of rectifiers in parallel; the constant current limit at 28 A, which protects the rectifier from overloads caused by battery recharging or system faults; and the current foldback, which is provided below 40 V so that the rectifier is completely self protecting when it is used without a battery.

Reliability

The Rectifier No. 160 is designed for a reliability of 20 years

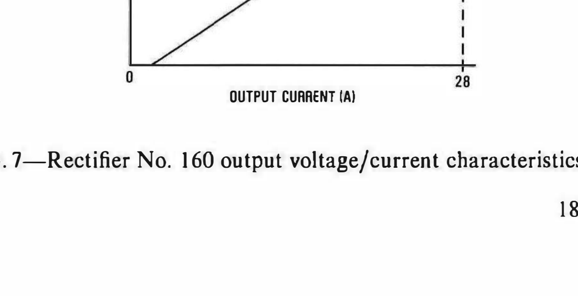


FIG. 7—Rectifier No. 160 output voltage/current characteristics

MTBF. This MTBF, coupled with the 1 in 5 rectifier redundancy and the 1 h battery reserve, allows the PER to meet the overall reliability requirements of System X. High reliability is ensured by the use of high-quality conservatively-rated components and careful circuit design to prevent components from being overstressed by transient conditions. All production rectifiers are subjected to a 48 h test at full load in an elevated temperature before final inspection and delivery.

BATTERIES

A major factor in the development of a complete DC power equipment rack has been the availability of batteries that require a minimum of maintenance once installed, and do not release unacceptable products into the environment. During the initial phases of the PER development, consideration was given to the types of batteries which were available in the market place, and which would meet the following product specification:

(*a*) be small enough to be installed in the available rack space,
(*b*) provide the required stand-by,
(*c*) not pollute the rack environment,
(*d*) require minimum of installation and maintenance,
(*e*) be suitable for charging at a constant potential of 2·27 V per cell,
(*f*) be intrinsically safe in the operational environment,
(*g*) be cost effective, and
(*h*) have a designed life of 10 years.

There was no battery produced in the world that would meet all aspects of the above specification. The British battery industry, however, agreed that with BT taking the lead, there was a potential home and export market for such batteries. Hence, with application and evaluation engineering being provided by BT, and the development production engineering and funds being provided by the industry, a battery suitable for the PER application was developed and approved by BT.

Gas-Recombination Battery

In the conventional stand-by Planté battery[3], which has hitherto been used for many years by BT, the plate electrodes are: POSITIVE—pure lead, and NEGATIVE—a lead compound pasted to a lead-antimony alloy grid, the electrodes being immersed in an electrolyte of dilute sulphuric acid. When this type of cell, which is being charged at a constant potential, reaches its theoretically fully-charged state, the charging current reduces to a low value (trickle charge). At this stage further electrochemical reactions take place and hydrogen and oxygen, which are evolved at the NEGATIVE and POSITIVE electrodes, respectively, are liberated to the environment via the screw-cap vents in the cell lid. Clearly, a battery that behaves in this manner is unsuitable for rack mounting with other equipment.

There are various types of cell construction that overcome to a large extent some of the gassing problems associated with *flooded-electrolyte* cells. However, the battery used on the PER uses an oxygen recombination and starved electrolyte principle[4]. In this type of cell, both POSITIVE and NEGATIVE electrode plates are in the form of a flat grid, cast from a special lead-calcium alloy or pure lead. Appropriate lead compounds are pasted onto each grid assembly, and plates of opposite polarity are interleaved together and mechanically separated by a thin layer of low-resistance absorbent material (Fig. 8). The complete assembly is made to fit snugly into a container moulded in flame-retardent acrylonitrile/butadiene/styrene (ABS), onto which is fitted a lid, of similar material, which is permanently bonded by welding to the top of the container to provide an acid- and air-tight seal. The POSITIVE and NEGATIVE terminal pillars pass through a compression seal in the lid (Fig. 9). Each cell is fitted with a re-sealing pressure-relief valve, set to operate safely when the internal pressure in the container exceeds 27·6 kPa (4 lbf/in^2).

In the final stages of manufacture, an accurately metered volume of dilute sulphuric acid is introduced into the cell under vacuum. This electrolyte is immediately distributed

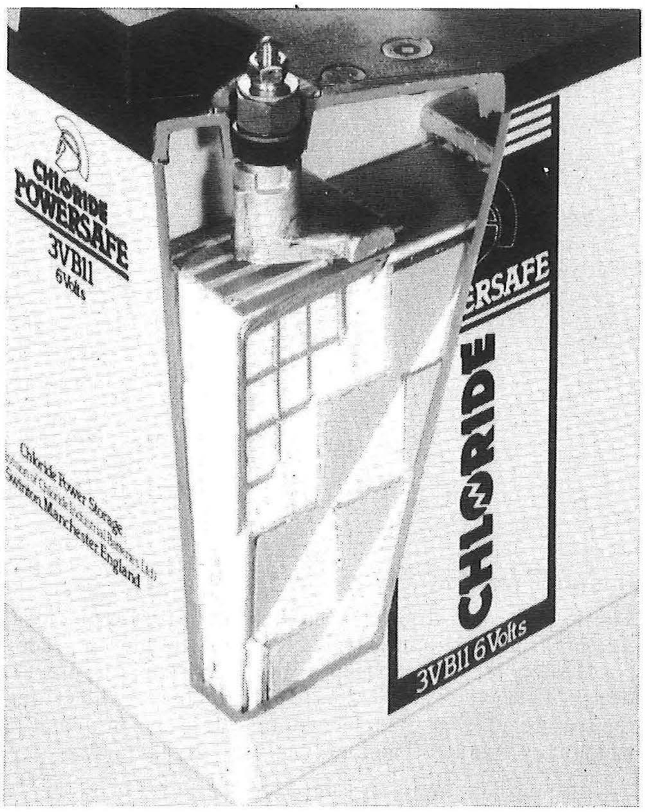


FIG. 8—Cut-away section of gas-recombination battery

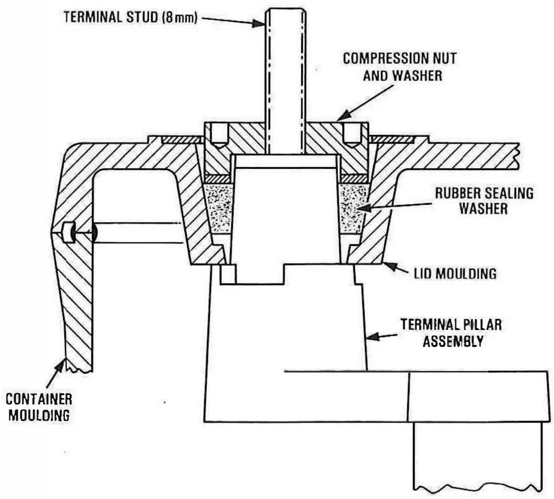


FIG. 9—Section through pillar seal

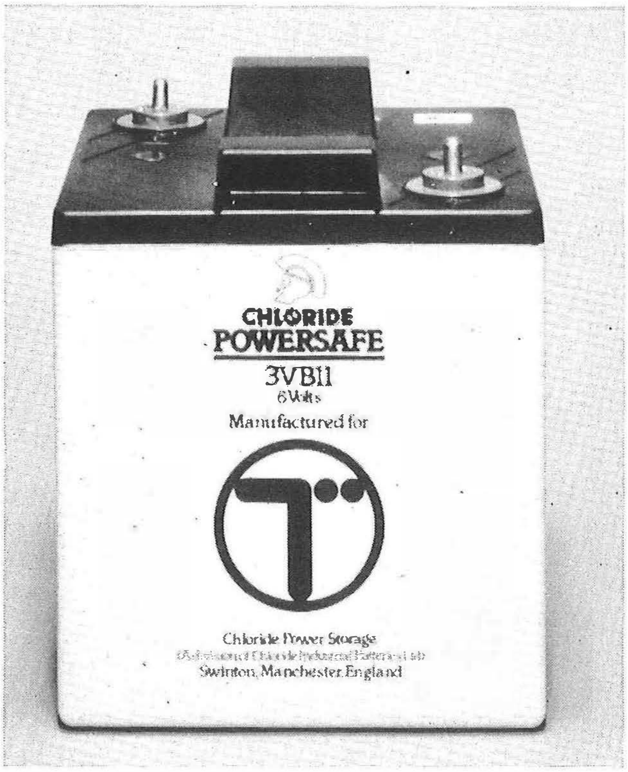


FIG. 10—Monobloc 6 V gas-recombination battery

throughout the separators by capillary action; hence, there is no free electrolyte in the cell container. Both the density and volume of this electrolyte are carefully controlled, since they determine the final electrical characteristics of the cell and its service life.

For the PER, 3 cells are assembled into a single container, and internally connected in series to provide a monobloc unit (Fig. 10) with a nominal potential difference at the terminals of 6 V and an energy density of 25·8 W h/l (the energy density for a Planté battery is 8·7 W h/l). The unit can be continuously floated without loss of charge at a constant potential of 2·27 V per cell.

Because of its high energy density, a nominal 48 V battery consisting of 8 monobloc units can be accommodated on one shelf of a PER and, when discharged to an end voltage of 1·9 V per cell, can provide 2 kW h of energy. Monobloc construction in 3-cell units reduces the number of external connections, and the relatively light weight of the monobloc unit (approximately 24 kg) enables them to be installed without mechanical aids.

CHEMISTRY

At the commencement of charge, both POSITIVE and NEGATIVE plates can be assumed to be reduced to lead sulphate ($PbSO_4$). During charging, a chemical action takes place, which converts the lead sulphate on the POSITIVE plate to lead peroxide (PbO_2) and the NEGATIVE plate to spongy lead (Pb). This reaction continues until there is no more lead sulphate to convert; at this point, the cell is theoretically fully charged. However, in practice a constant-potential charging source continues to provide a trickle-charge current into the cell, at which point an overcharge electrochemical reaction is initialised, causing electrolysis of water which generates and releases oxygen and hydrogen gas.

The gas-recombination lead-acid cell prevents this release of hydrogen and oxygen occurring by arranging for the NEGATIVE plate to have a higher capacity than that of the POSITIVE plate. Hence, as the cell approaches full charge, oxygen is evolved at the POSITIVE plate, before the NEGATIVE plate becomes fully charged. The oxygen evolved at the POSITIVE plate readily diffuses to the NEGATIVE plate, where it is electrochemically reduced to water by the reactive spongy lead, so reducing some of this spongy lead to lead sulphate. In the conventional sense the NEGATIVE plate is not fully charged (that is, evolving hydrogen), but is at equilibrium with the oxygen recombination reaction.

The pressure relief valve in the sealed container restricts the internal pressure, which assists recombination by retaining the gasses within the cell long enough for diffusion to occur. Thus, this type of cell may be overcharged sufficiently to convert all of the active material without loss of water in the form of hydrogen and oxygen. The rate of overcharge is important since, at a continuous high rate of overcharge, the NEGATIVE and POSITIVE plates become out of phase in recombination equilibrium terms, so that the recombination efficiency is below 100% and small volumes of hydrogen gas are released from the cell.

CONCLUSION

The evolvement of rack-mounted DC power plants described in this article is a major advance forward from the traditional large centralised power plants. The choice of the TEP1H practice as a mounting frame on which to build the PER was influenced by the immediate application for use with System X. However, the various off-the-shelf module units that have been developed now provide a concept with flexibility of design from which other systems, for main network exchanges and customer exchanges, can be readily engineered on equipment practices to suit the application. An example is a system compatible with the small digital-switching telephone exchange system UXD5, which has been well received.

Development for the future suggests a need to improve the overall system conversion efficiency between the AC mains input power and the power which is dissipated at the various voltages required by the individual switching circuit elements. One way to achieve this may be to rationalise the intermediate 48 V interface and hence produce an even more integrated power system to include battery stand-by capacity, engineered into a rack shelf rather than a dedicated power equipment rack.

ACKNOWLEDGEMENTS

The authors wish to thank Chloride Power Storage for providing Fig. 8 and Fig. 9, and colleagues in the Telecommunications Power Division, British Telecom Inland, for their helpful suggestions.

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The New British Telecom Speaking Clock

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UDC 621.395.91: 529.78

After 20 years service the existing British Telecom speaking clocks are to be replaced. The new clocks use microprocessor control and a digital speech recording. This article describes the operation of the new clocks and briefly outlines the national distribution arrangments for the service.

INTRODUCTION

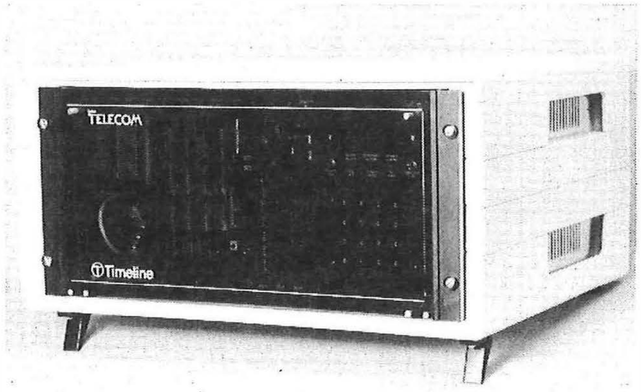
The original speaking clock service, known as *TIM*, started in 1936 with the installation of a pair of clocks at Holborn, in London. The service was then extended in 1942 with the installation of a second pair of clocks at Liverpool, and a secure distribution to the whole country was set up by using a duplicated ring circuit. It was considered uneconomical to retain the original clocks beyond 1963 and a replacement was therefore designed and installed*. These clocks are still providing British Telecom's (BT's) Speaking Clock Service, recently renamed *Timeline*, which is distributed nationally from London and Liverpool.

The existing clocks consist of an electric motor driving a magnetic drum, which holds phrases and tone recordings, and a precision set of gears and cams that position playing heads to select the appropriate phrases. The mechanical nature of this equipment means that regular maintenance is required and an extensive overhaul would be necessary in 1984. With the advent of the microprocessor and relatively-cheap storage for speech samples, a digital equivalent to the existing clock is now a viable alternative. It is therefore more economic to replace the existing clocks with a modern-technology system rather than to proceed with the costly overhaul. As no suitable electronic clocks were available, a design based upon the established automatic call recording equipment (ACRE) microprocessor system has been developed by BT. The new clock is a low-cost physically-compact equipment (see Fig. 1) with a high degree of flexibility, including the ability to cater for different languages, which not only satisfies BT's requirements, but also gives excellent potential for use outside the UK.

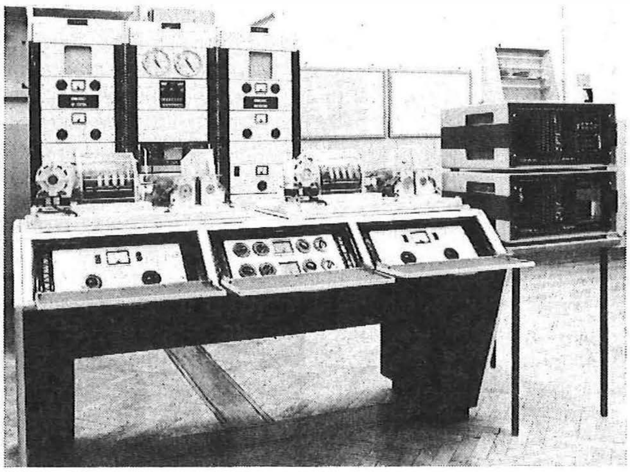
BASIC DESCRIPTION

The new clocks retain the format of the existing equipment with a time announcement every 10 s, specifying hours, minutes and seconds, followed by three 100 ms bursts of 1 kHz tone at 1 s intervals. The exact time is denoted by the beginning of the third pulse.

Each clock is microprocessor controlled and has its own high-accuracy temperature-controlled crystal oscillator for timekeeping, but to ensure a higher level of precision, it can be compared and corrected to a remote reference source (see Fig. 2). This could be a radio time standard as transmitted from the Rugby radio station, but for greater security BT will continue to use a signal derived from the National Physical Laboratory's atomic resonance standard fed via a land line from Rugby. At 09.55 hours each day the clock compares itself to the standard and applies correcting factors



(*a*) The new speaking clock.



(*b*) Comparison of the existing and the new speaking clocks

FIG. 1—Existing speaking clock and its digital replacement

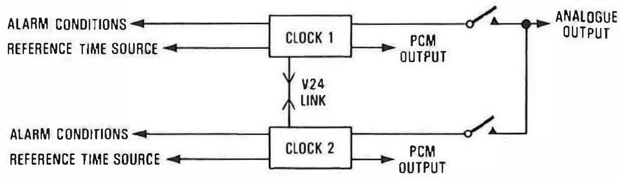


FIG. 2—Clock pair configuration

† Local Exchange Services, British Telecom Inland

* WALKER, R.R. The New Post Office Speaking Clocks. *Post Off. Electr. Eng. J.*, Apr. 1963, **56**, p.1.

for both time deviation and oscillator drift. The accuracy of the clock is expected to be within ±5 ms per day.

The speech and tone are encoded by using pulse-code modulation (PCM) techniques and then stored digitally in electrically-programmable read-only memory (EPROM). Provision is made for high-quality analogue and PCM outputs, the speech quality being superior to existing synthesised systems. Although the clocks can operate independently in the BT network, they are operated in pairs to give a very high degree of security. Pairs of clocks are being installed at both London and Liverpool to replace the existing equipment. Each clock in a pair monitors the other and retains information to restart it without impairing its accuracy. Normally, one clock in a pair provides the output for distribution, but change-over is effected automatically under fault conditions, or manually for maintenance purposes. The use of solid-state technology means that unlike the existing mechanical clocks, the new speaking clocks require no routine maintenance. If however, maintenance is required as a result of a fault, diagnosis is simplified by the provision of a visual alarm and a display identifying the type of fault.

To enhance its flexibility, the clock can be run from a single +5 V supply, and space is provided for mounting a suitable commercial power unit which may have any desirable AC or DC input.

NATIONAL DISTRIBUTION

As the Timeline service is extensively used and is considered to be a national reference, every effort is taken not only to ensure its accuracy but also to ensure its availability. The new clocks will use the existing secure distribution system (see Fig. 3), which consists of 2 rings: one supplied from the clocks in Kelvin House, London and the other supplied from the clocks in Lancaster House, Liverpool. Each ring terminates at 15 distribution centres which, in turn, supply appropriate exchanges via local rings or spurs. Under normal circumstances the distribution centres in the North of Britain use the Liverpool source and those in the South the London source.

The network is secured in 2 ways, the first being the automatic switching from one ring to the other at the distribution centres should reception on the primary link fail. The second option is a manual connection of both rings to one clock installation should the other installation fail. Plans are in hand for an additional clock installation to be provided as a back-up facility should either the London or Liverpool clocks need to be withdrawn from service for a period of time.

HARDWARE

Each clock is approximately 480 mm wide, 420 mm deep, by 220 mm high and comprises a shelf containing printed-wiring boards (PWBs) and a plug-in power unit (see Fig. 4). The plug-in power unit incorporates a control panel fitted with a hexadecimal keypad, control switches, an indicator display and a 6-digit display, which normally shows hours, minutes and seconds. The complement of PWBs is normally composed of 4 memory boards, each containing 64 Kbyte of EPROM, one processor board and one codec board. A further board can be provided with a PCM output for the digital network, and a radio-receiver board may be fitted if comparison with a radio time source is required.

At the rear of the rack, provision is made for external connections. These include sockets for 2 data links (one for future expansion and one for inter-clock communication), analogue output, PCM output and wrapping pins for external connection of power and alarms.

Processor Board

The processor board, known as the *CP85 unit*, was originally developed for the ACRE system and uses an 8085 microprocessor. In this application it has been slightly modified to permit off-board control of two interrupts plus control of one interrupt by an on-board timer-counter. This counter is

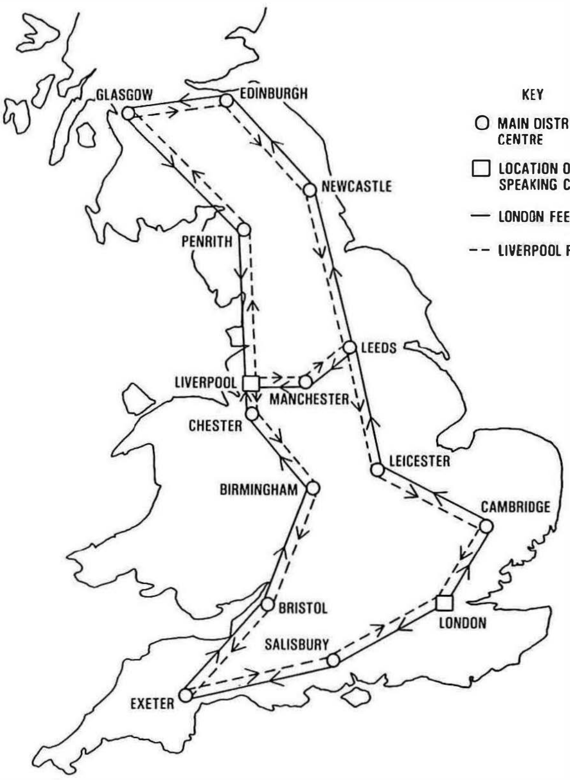


FIG. 3—Speaking clock distribution

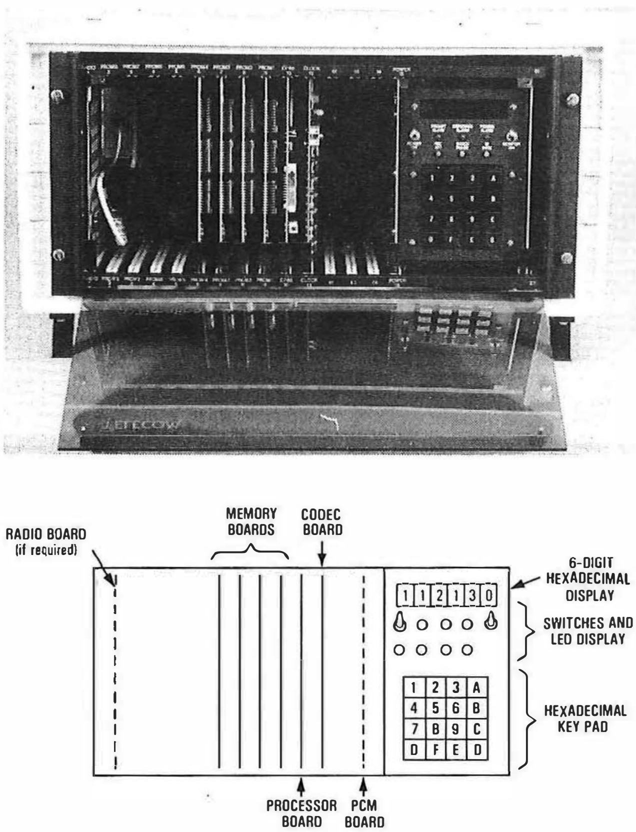


FIG. 4—Physical layout of the clock

under control of the high-stability temperature-controlled crystal oscillator and is used by the processor to generate the basic time unit. The timer is repeatedly initialised and decremented to zero producing an interrupt to the processor every 1 ms. The board has capacity for up to 2 Kbyte of random-access memory (RAM) and up to 12 Kbyte of EPROM, which are used by the clock operating system. An 8-bit port is used to control an extended address bus for bank switching of the speech memory.

Codec Board

The codec board contains circuit elements to fulfil the following functions:

(*a*) clock timing signals from the temperature-controlled 6·144 MHz crystal oscillator,
(*b*) digital-to-analogue speech conversion,
(*c*) audio amplification,
(*d*) audio output switching for change-over between clocks,
(*e*) prompt and deferred alarms,
(*f*) detection of the reference timing signals received via a landline, and
(*g*) bus timing signals required by the processor.

Fig. 5 illustrates how the speech output is generated. The processor fetches the selected bytes of stored PCM data from memory and puts them in a first-in-first-out (FIFO) memory device. A serial data stream is then output from the FIFO using a 64 kHz clock. When working in an analogue environment, this clock is derived internally, but if a digital output is required, a synchronised clock is obtained from the PCM interface board. This data stream is then fed into a standard A-law PCM codec, to give an analogue signal which is filtered and amplified for output. The resulting signal is then monitored for alarm and change-over purposes. To reduce demands made on the processor for the time-consuming transfer of digitised speech to the FIFO, a circuit is used to generate the PCM code for silence, and this is ENABLED when the FIFO is empty.

Memory Boards

The memory board used is a standard ACRE memory unit designed to take both EPROM and RAM, but in this application it is only equipped with 64 Kbyte of EPROM, which is used to hold the digitised speech. Up to 7 memory boards can be provided and these are selected by an extended address bus generated on the processor board.

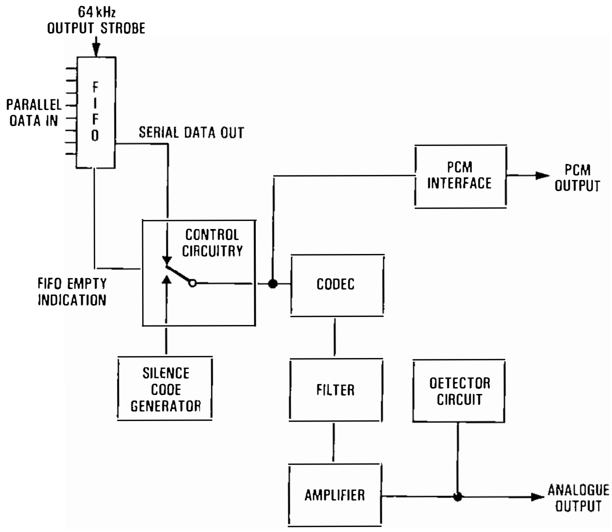


FIG. 5—Analogue and PCM outputs

Power/Display Unit

The clock operates from a +5 V supply and this is derived from a standard −48 V input from any suitable commercial power pack. Space is provided for mounting this power pack on an aluminium panel forming the right-hand side of the unit, thus giving flexibility and eliminating dependence on a single design. Internal −12 V and +12 V supplies are derived from the +5 V supply by using a resin-encapsulated circuit, and a low current −5 V supply is derived directly from the −12 V supply by using a regulator. Circuitry for the +12 V, −12 V and −5 V supplies is mounted on a single PWB together with interface circuitry, and a second PWB is provided for an audio monitor amplifier. All voltage supplies are monitored and failure of any one will cause an alarm and change-over to the other clock in a pair. A separate external −48 V is used to power the alarm circuitry, but this can be switched to the internal +5 V if required, although this does affect the overall security of alarms.

A third PWB is located behind the control panel for the display and keyboard components. The 6-digit display on the front panel is normally used to show time, but it can also be used under control of the keypad to display other items of information necessary for management of the clock. The remaining items on the control panel are 2 switches (one for power and the other for the audio monitor output), and 7 light-emitting diodes indicating the following functions:

(*a*) power on,
(*b*) power alarm,
(*c*) one second pulse from the reference time source,
(*d*) in service,
(*e*) prompt alarm,
(*f*) deferred alarm, and
(*g*) alarm receiving attention.

PCM Board

A PCM output is required from the clock for distribution on the digital network. Space has therefore been provided in the rack for a PWB containing a suitable interface which will conform to the CCITT† standards for 30-channel PCM. The design of this PCM board has been left until the later stages of the development in order to take advantage of new large-scale integrated circuits which are becoming available.

Radio Board

Provision has been made on each clock for a PWB on which is mounted a commercial radio receiver. This can be used, in conjunction with an active aerial, to provide a reference 1-second pulse derived from one of the international radio standard time transmissions. The British radio time standard is transmitted from Rugby, but because this does not offer the same security as the existing land line transmissions, it is intended to use the established reference source for the BT installations.

AUTOMATIC CHANGE-OVER

Change-over from one clock to another is effected either under manual control from the keypad or automatically under fault conditions. Manual change-over is controlled by software and automatic change-over is either hardware or software controlled. Automatic change-over will occur for the following reasons:

(*a*) power failure,
(*b*) unit removed,
(*c*) fault conditions detected by software, and
(*d*) audio output failure.

† CCITT—International Telegraph and Telephone Consultative Committee

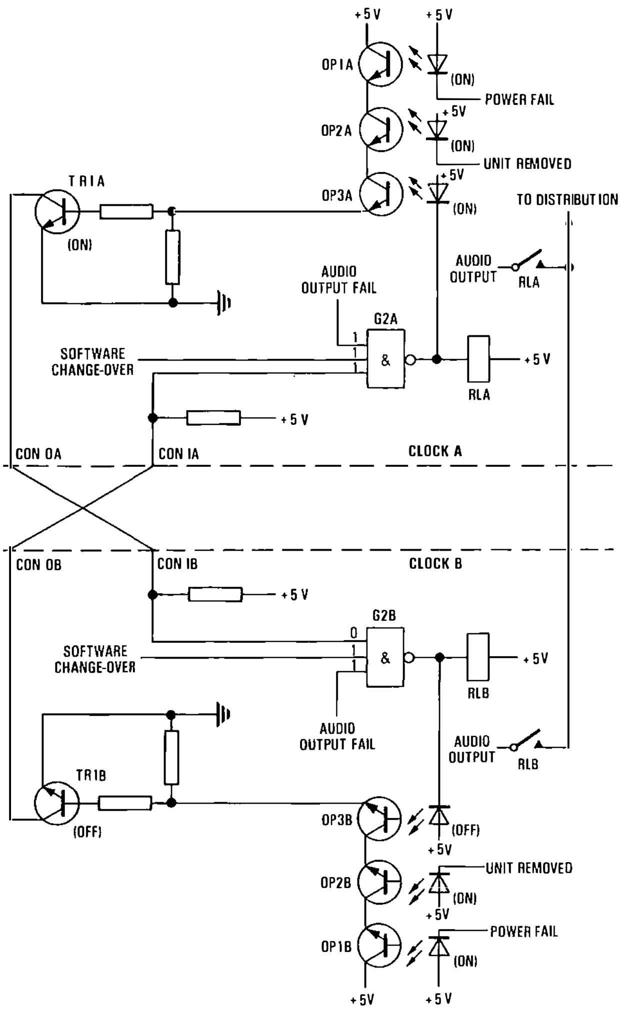


FIG. 6—Change-over circuitry

On failure of one clock it is important that the 2 analogue outputs are not connected together otherwise speech distortion may occur. This is prevented by connecting each clock-output relay in a bistable circuit so that only one clock ouput can be distributed at any one time (see Fig. 6). Under normal conditions gate G2A has all ones on its inputs and thus relay RLA is operated, connecting the clock A audio output to line. The opto-couplers OP1A, OP2A and OP3A hold transistor TR1A ON, which in turn holds gate G2B output HIGH. Thus relay RLB can be operated only when allowed to by the A system. Either under software control or an audio output failure, gate G2A output will go HIGH and release relay RLA. Transistor TR1A is turned OFF via opto-coupler OP3A and all the inputs to gate G2B become HIGH resulting in an output to operate relay RLB, which connects the B audio output to line. The resulting condition on connector CON OB ensures relay RLA cannot re-operate. If clock A is in service and either the power fails or a unit is removed, then transistor TR1A is switched OFF from either opto-coupler OP1A or OP1B and change-over is effected in a similar manner, but the condition on connector CON OB is used to ensure relay RLA is released. Change-over from system B to A follows the equivalent procedure.

SOFTWARE

The software is organised in 6 parts (see Fig. 7) comprising 3 interrupt routines: RST5.5, RST6.5, RST7.5; and a round-robin control routine to select the running order of 2 pro-

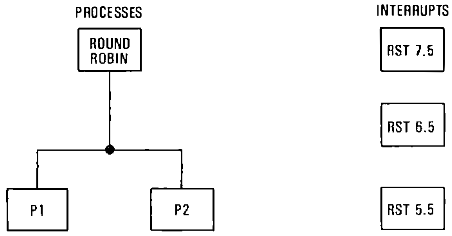


FIG. 7—Software organisation

cesses known as *P1* and *P2*. RST5.5 is an interrupt routine which is activated every 10 s to compare time between the clocks in a pair. RST6.5 is a routine run once a day to compare the internal time with the reference source, and RST7.5 is a routine activated every millisecond to provide the basic timing element. Process P1 selects the appropriate speech phrases to be transmitted and transfers the PCM encoded speech from memory to the FIFO for output. Process P2 deals with information input from the keyboard and output to the displays.

RST5.5

The RST5.5 interrupt is used at 10 s intervals to cross check the relative drift between clock shelves, and if this has become excessive an alarm is given. Normally the interrupt is enabled 1 s before a 10-second boundary until the same interrupt is received from the other clock; on receipt, the difference from a 10-second boundary is calculated. During the start-up of a clock shelf, RST5.5 is ineffective until the time and date have been received either from the other shelf or via a keyboard entry; then, when the interrupt next occurs, the clock is allowed to run.

RST6.5

The RST6.5 interrupt is used for the daily update from the primary reference standard between 09.55 hours to 10.00 hours each day, and also during the initialisation of a clock. The difference between the 1-second pulses received from the reference and the time in the clock shelf is calculated in 0·1 ms units, and compensation made for any known signal distribution delays. Three such differences are calculated for successive pulses, checked for consistency, averaged and used to adjust the clock to the correct time. For regular updates this difference is divided by the number of days since the last update, added into the previous value of drift and used in the calculation of the automatic clock correction. The value of difference forms part of the data passed between clock shelves every 10 s so that if one shelf loses power its drift information is not lost. After reception of 3 consistent pulses this interrupt is masked until the next update.

RST7.5

The RST7.5 interrupt is derived from the 6·144 MHz temperature-controlled crystal and is used to generate the basic timing unit. A timer chip on the processor board is programmed as a rate generator to divide by 1536, and results in an interrupt to the processor every millisecond. This basic timing interval is then counted in registers to provide both time and date. At the 1-second, 4-second, 10-second, 1-minute and 1-day boundaries, flags are set to enable routines within processes P1 and P2 to be executed, process P2 using the 1-second flag and the remaining flags being used by process P1. Output of the 100 ms 1 kHz tone bursts is also controlled by this interrupt, and care has been taken to keep the amount of processing to a minimum in order to minimise jitter caused by variations in processing delays.

Special conditions apply for the start-up of a clock when flags cause process P1 to reset the seconds count to zero after it reaches 3 seconds. This is necessary because time-outs are required up to 3 seconds, but the system must otherwise remain frozen, awaiting a trigger from the keyboard or the other shelf on RST5.5 or RST6.6.

Various other functions may also be performed under RST7.5; for example, the division factor for the 1 ms rate generator may be changed to add or subtract steps for correcting any time inaccuracies.

Round Robin

This is a very simple control routine called as a procedure by processes P1 and P2. It is the responsibility of each process to call round robin and allow the other processes to run. No provision is made for passing messages or suspending processes in this simple application, and round robin is fully interruptable.

Data controlling selection of each process is stored in a memory block consisting of 3 words, NEXT, STACK and ENTRY. NEXT holds the address of the ENTRY word of the block for the next process to run. STACK holds the stack pointer of the terminated process and ENTRY holds the address of the process initialisation routine, which is only used on start-up.

When a process is terminated, the stack pointer is saved in STACK and the address for the next block is given in NEXT. When a new process is run, ENTRY is interrogated to see if the process had been run before; if it has, a return is made to the address at the top of the stack. If it has not run before, the ENTRY word is cleared and the initialisation routine is executed.

Process P1

Process P1 is responsible for topping-up the FIFO with bytes of PCM encoded speech from memory; it also contains routines performed when appropriate boundary flags are set.

Flags are set on start-up and on the 4-second, 10-second, 1-minute and 1-day time boundaries. The 4-second routine is used to apply 0·1 ms time corrections, if required. The minute routine is used to apply hour and second corrections for changes between normal and summer time, and leap second adjustments; both are executed at a time set from the keypad. The day routine clears accumulated error counts used for alarm purposes. The 10-second routine is the most complex and controls the transmission and reception of data between clock pairs and the selection of the appropriate speech phrases. Data transmitted between clocks includes the time, date, crystal-drift information and an indication of whether an update has been entered. After reception of the data, a test is made to see if this data agrees with the data already held in the clock. If it is outside set limits, either a manual correction has been applied to one clock, in which case the other clock will be automatically updated, or an alarm is given. Selection of the appropriate text for the next announcement is determined from the time in conjunction with control tables and phrase tables. The control table defines the structure of the output, for example, phrase, pause, hours, minutes, seconds, while the phrase tables specify the start address and the length in bytes of the appropriate text in memory.

A separate routine is used to transfer data to the FIFO. A test is made to check if the FIFO is full; if it is not, then a byte is transferred to it. The phrase start address is then incremented and the number of bytes in the phrase to be transmitted decremented. The extended address bus arrangement results in speech memory being divided into 4 Kbyte blocks and 64 Kbyte pages, so after each byte is ouput a check is made to see if the next byte location crosses a 4 Kbyte or a 64 Kbyte boundary so that switching can be executed, if appropriate. The process is repeated until either the FIFO is full or the last byte in the phrase is reached; then processing of other tasks continues. The FIFO needs a byte of information every 125 μs in order to keep up with the output speed, but because the processor has many other tasks, the data is input at a much faster rate.

Process P2

Process P2 deals with inputs from the keypad and controls the display of information. Inputs are subject to a validity check before being accepted; for example, a date of 29 February would not be accepted outside a leap year. The main facilities available from the keypad are:

(*a*) input time,
(*b*) display time,
(*c*) input data,
(*d*) display date (year, month, day),
(*e*) display fault number,
(*f*) alarm receiving attention,
(*g*) clear alarm,
(*h*) change-over to other shelf,
(*i*) display propagation delay for standard time reference signal,
(*j*) amend propagation delay for standard time reference signal,
(*k*) display clock drift,
(*l*) amend clock drift, and
(*m*) miscellaneous test facilities.

The 6-digit display mormally shows the time in hours, minutes and seconds; other information is displayed under control of the keypad. Use is made of the 1-second flag set in the RST7.5 routine to flash a display character as a prompt asking for data to be input (see Fig. 8).

DIGITISED SPEECH

Copies taken from the original voice recordings for the existing Mark 3 Speaking Clock were used as the analogue speech source for digitisation. Digitised copies were made and edited using techniques developed for the System X voice guidance announcements. The analogue recording was passed through a codec to convert it to digital (PCM) form, and the output stored in a microcomputer system. Speech editing was then effected by trimming unwanted periods from the beginning and end of each speech element while listening to the reconstituted speech and analysing a graphical speech representation produced by the editor. This process enabled the speech memory requirement to be shrunk to 256 Kbyte of EPROM by forming numbers in the range 21–59 from 2 concatenated speech elements; for example, *twenty* followed by *five* gives *twenty-five*. One byte of memory represents 125 μs of analogue sound, so the complete 12-hour

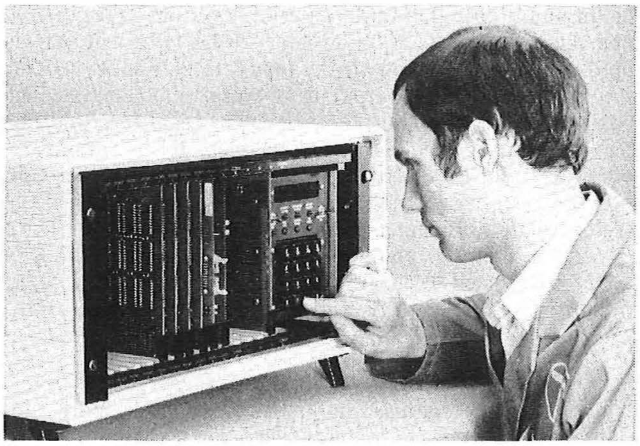


FIG. 8—Information being entered manually via the keypad

announcement cycle for the clock had been contained within a digital recording representing approximately 33 s of speech.

Compacting speech into a small digital recording is, however, very time consuming, and as memory costs are decreasing it has become more economical to use more memory and minimise speech editing. A high-capacity memory board containing 0·5 Mbyte of EPROM has therefore been developed for future use.

ACCURACY

The datum point of the existing clock is at the beginning of the third tone burst and is guaranteed to within ± 50 ms of the atomic clock at the National Physical Laboratory. In practice, however, the accuracy is considerably better and it is expected that the new clock will be at least as accurate as the existing one, which is normally within ± 5 ms.

Accuracy of the new clock is dependent primarily upon the high-stability crystal oscillator, which controls the timing process. Its accuracy is dependent upon 3 features: the initial setting, drift with age, and temperature stabilty (see Table 1).

The most significant factor affecting clock accuracy is the variation due to temperature in oscillator stability. This is, however, most prevalent at the ends of its specified temperature range and as temperatures are generally restricted to normal room conditions, the stability should be far higher than the figure given in Table 1.

TABLE 1
Crystal Oscillator Specification

Parameter	Accuracy
Temperature stability	± 1 in 10^7 (−10°C to +60°C)
Initial accuracy	± 10 in 10^6
Aging	± 2 in 10^6 per annum

To minimise the effect of oscillator inaccuracies, the clock compares itself to a reference source once a day and then applies a correcting factor of ± 0·1 ms every 4 s until the correct time has been achieved. In addition to this, the mean historical deviation from the standard is used to predict drift in the next 24 hours and this correction is applied in 0·1 ms steps at regular intervals throughout the day. The drift compensation is, in effect, a fine tuning of the oscillator applied every day according to its historical behaviour.

Additional factors affecting the accuracy are processing delays in outputting the tone, which have been minimised, and the resolution of reference signal propagation delays. In theory, the clock could drift by ± 15 ms a day, but its operational accuracy is likely to be significantly better than this.

ALARMS

Four different alarm outputs are provided on the back of each clock; these are unit removed, power failure, prompt and deferred.

The unit removed and power failure alarms are hardware functions only, independent of the internal power supplies, and indicate if any PWB has been removed or any internal power supply has failed respectively. Power for these is derived from an independent external −48 V source, but the internal +5 V could be used with a slight reduction in security. Prompt and deferred alarms, except output-speech failure, are initiated in software; the nature of the alarm being shown by the display of a fault number. Prompt alarms are defined as failures requiring immediate attention; for example, the time difference between clocks is too great. Deferred alarms are defined as conditions that do not affect service, for example, dates are different between clocks.

Any alarm condition indicating a service-affecting fault will result in the clock output being disconnected and an attempt being made to switch the other clock into service. If a deferred alarm is given and the second clock fails to respond because it has its own alarm condition, then the alarm will be changed to a prompt alarm.

CONCLUSION

Development of a new speaking clock has led to production of low-cost equipment of high accuracy and reliability which does not require any regular maintenance. The first pair of production clocks have been installed in Kelvin House, London, and are now undergoing final testing before taking over the Timeline service. The announcement will be the same as that of the existing clocks, but it can be readily changed as demonstrated by the clocks speaking in English, French and Swedish in the British Pavilion at the Telecom 83 Exhibition in Geneva.

ACKNOWLEDGEMENTS

The author wishes to express his gratitude to colleagues in Local Exchange Services Department for their assistance in the preparation of this article and in particular to the staff of the Circuit Laboratory who have provided active support to this development.

A Communication Program for On-Line Systems and its Use in Man–Machine Language Translation Work

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UDC 681.3.022 : 681.3.068

A versatile on-line communication program has been developed. Its design and the implementation of a man–machine language translator are discussed. The program simultaneously interworks with a communications line, a visual display terminal and disc-based command files, and enables a great variety of communications-related tasks to be performed. In the translator application, a user-friendly interface has been implemented to protect the user from the need to master the details of a complex set of transactions which are taking place on his behalf.

INTRODUCTION

With the low cost and ready availability of small computer systems, it has become possible to consider using dedicated microprocessors in new applications; this article describes a program which was developed to fulfil a need in several related areas.

Parodoxically, an area which has received little computer-assisted attention is the operation of computer-based systems. Many large computer-controlled systems which do not fully meet the needs of all of their users have been developed. For instance, in the earlier testing of System X exchange models, there was a gap in the facilities which were available for the repetition of a series of tests. Typing in command data from a simple terminal to configure and operate the exchange model required much manual effort. There was a need for a facility that enabled a user to define and then apply a set of tests to the model, with appropriate recording and analysis of the results at a later stage. The program described in this article was initially developed to fulfil this need.

Another arca which needed some improvement was the occasional access of System X exchanges in the field by administrative staff. The problem here was a lack of familiarity with the fairly complex command set which is available through the usual interface to the System X exchanges. The solution was to extend the original communication program; this application of the program has been described elsewhere‡.

DEVELOPMENT OF THE PROGRAM

As mentioned above, the program was initially developed to assist in the process of automating the testing of System X models. Enhancements were then provided to make the program support a number of more general communications functions, though still within the concept of providing asynchronous communication with a range of computer systems. The aim of the development was to provide a number of useful extra facilities by replacing a directly-connected terminal with the system shown in Fig. 1.

The facilities provided include the following:

(*a*) The ability to repeat a defined series of commands (called a *command file*) under user control, independently of the capabilities of the remote computer.

(*b*) The ability to log a series of transactions to the printer and to disc for later analysis. In the testing field, the ability to compare transaction logs is of benefit in performing regression testing of different versions of the system under test. The transaction logs are compared by using a separate file-comparison program to identify altered responses to the same test stimuli.

(*c*) The ability to perform basic serial file transfer between machines.

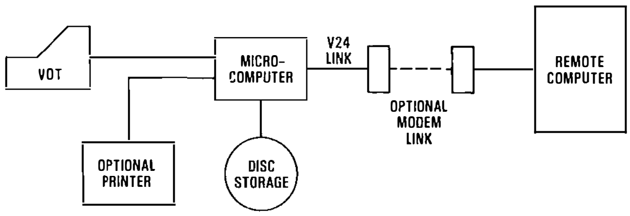


FIG. 1—Computer configuration

The program was designed for a Z80-based microprocessor running the well-known CP/M operating system developed by Digital Research Inc. However, the design principles involved could be applied to other types of computer system. Fig. 1 shows the way in which the local microcomputer is connected to the remote computing system via a standard asynchronous line (V24/RS232); the terminal, normally a visual display terminal (VDT); and an optional local printer.

To support communication with a variety of computers requiring variations in line protocols, a flexible configuration system was provided for engineering users. This allowed the user to change protocols without leaving the program. Parameters which can be configured without re-compilation of the program include the following:

(*a*) baud rate;
(*b*) line mode (that is, simplex or duplex);
(*c*) characters which define end-of-line sequences for transmit and receive;
(*d*) *transaction-complete* character(s) (if any) used by the remote computer;
(*e*) time-outs used to determine when to send the next command, in the absence of any *transaction-complete* indication;
(*f*) the definition of a *start-up* command to be executed when the program is first run, which can initiate a complex set of transactions, if necessary, and further modify the operating mode of the program; and
(*g*) dimensions for certain internal arrays which may require modification to cope with particular applications.

In order to give flexibility, a number of complete protocol definitions can be placed in a file which the user has previ-

† At the time of writing, Mr. Johnson was in the System X Development Department, British Telecom Major Systems
* At the time of writing, Mr. Nathan was in the Occupational Psychology Division, British Telecom Headquarters
‡ NATHAN, T. D., and JOHNSON, D. Communicating with System X. *Br. Telecom J.*, Winter 1982/83, 3(4), p. 2.

ously created by using the standard editor program. The user selects the protocol definition required by means of a keyword which is supplied when the program is run, and can select a new protocol while the program is running.

When the above facilities were working in the program, the program designer was approached by staff in the Occupational Psychology Division of British Telecom. They were looking for a means of providing a user-friendly translation facility whereby the man–machine language could be defined separately from the transactions which were needed to communicate with the remote computer system. The aim was to allow operational staff to perform complex transactions with System X exchange processors. The necessary commands were added to the existing program to provide this second capability.

FLOW OF PROGRAM CONTROL

A simplified diagram of the operation of the program is shown in Figs. 2 and 3. Running in a loop, the program interleaves the checking for incoming messages from the remote computer with the processing of data from the terminal or command files. Whenever the system is waiting for data from the terminal, it continues to check for and process incoming messages, as shown in Fig. 3. This is necessary to prevent potential overrun of the input buffer.

Each line of data received from the terminal or a command file is checked for the presence of references to previously defined variables, which are then expanded by using an internal macro-processor. The line is then further checked to see if a command requiring local processing is present.

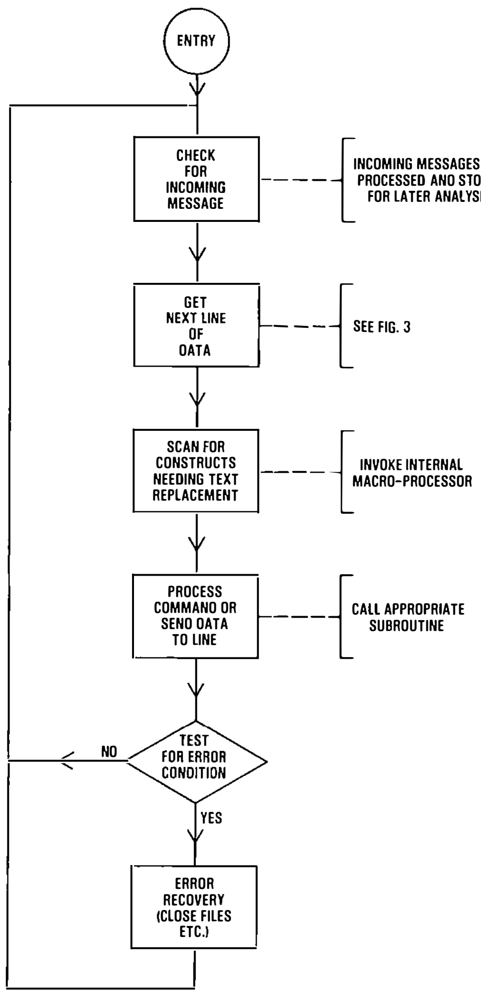
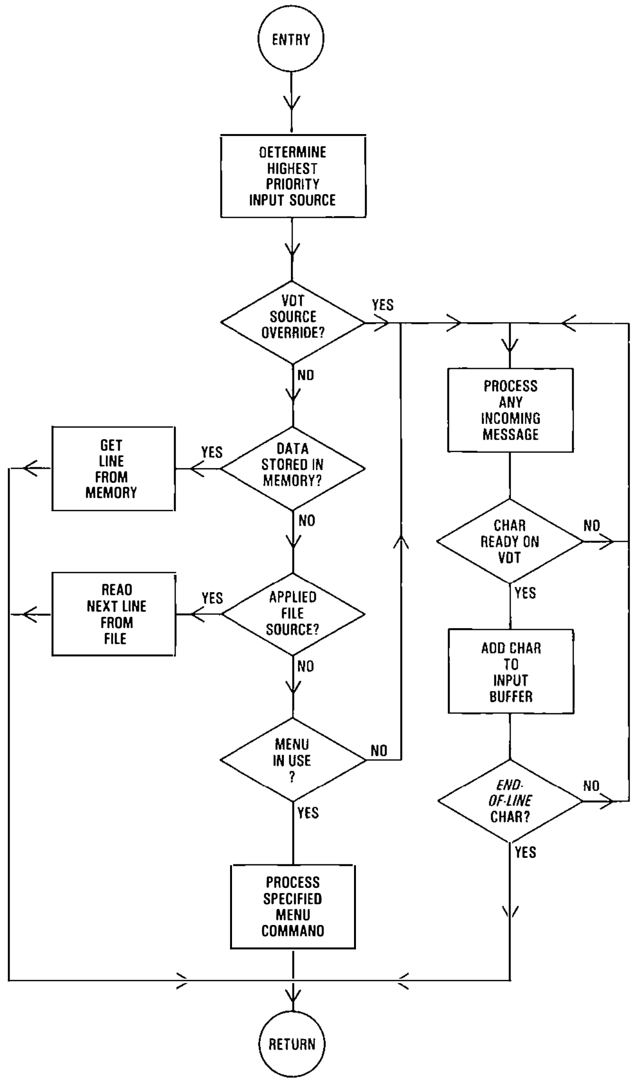


FIG. 2—Direct-mode processing loop



CHAR: Character

Note: A number of sources may take precedence over the VDT as the source of data. In particular, when a menu command is executed, the menu is displayed when input would normally come from the VDT

FIG. 3—Routine to get next line of data

Local commands are recognised by a keyword at the start of the line followed by a colon. If a local command is found, the appropriate command subroutine is called. This typically sets various internal flags, or modifies the source of further inputs. At the end of the subroutine call, a check is made to see if any error conditions which require special attention are flagged; for example, to close files or return control to the terminal. At the end of a command file, the next level of command file (if any) is entered. When command-file sources of data are exhausted, and before control is returned to the terminal, checks are made to see if any other logical sources of data are available. For instance, once the program is set up in a user-friendly mode, there is always a valid alternative source of data, this being a master menu command, which causes re-display of the available selections to the user.

MESSAGE FLOWS

The program uses interrupt-driven software routines to handle the buffering of communications with the remote computer system. The use of message-based buffering leaves the high-level language part of the program free to process data from the other sources on a polled basis, thus simplifying the design of the program.

All outputs from the microcomputer to the terminal, the printer, the disc and the line are performed in the usual way by using standard high-level language constructs. The treatment of inputs varies from device to device. Communications from the terminal are on a polled basis, whereas communications received from line are handled via interrupt-driven buffers, as shown in Fig. 4. Characters received from the line are stored temporarily (for a few milliseconds at most) in a hardware input/output (I/O) device. This device then generates an interrupt to the program, and a routine is executed to examine each character. Inputs other than the data from the line could profitably be buffered in this way, but this has not been necessary in the current implementation of the program.

Depending on the protocol selected, most control-character codes can be ignored at this stage, and it is convenient to reset the eighth bit of the character received. The accepted characters accumulate in a circular 2 Kbyte buffer, which has pointers to the start and end of the buffered data. Higher-level processing routines remove data from this buffer on a logical line-by-line basis, rather than a character at a time (the logical *end-of-line* character being user-defined in the protocol). This increases the efficiency of processing the data, and ensures that high-level language routines do not waste time examining every character received. When the high-level routines get a line of data, it is then stored in a string array, which can then be examined under the control of command files.

COMMAND PROCESSING

By default, the program starts off accepting its commands from the terminal, but in the translator application this is not desired, and so a start-up command is specified in the protocol; this immediately passes control to a disc-based command file, which then retains control for the whole of the session.

When the terminal is the source of data, the user can build up a line of data to be processed which will be examined by the program only when it is complete. The line may contain a recognisable local command but, failing that, the line is treated as data to be sent to line. The user can specify that the program should obtain its data from a command file, instead of the terminal, and then this file is processed line-by-line until the processing is complete, when control once again returns to the terminal. Processing of a command file can, however, be interrupted, should the user require.

Besides the commands which are valid when typed directly at the terminal, a number of commands which make sense only in a command file are available. These commands are used to provide conditional selection and decision-making capabilities. In all, about 30 commands are available. Some examples are shown in Table 1.

Each command begins on a new line and consists of a keyword followed by a colon. Most commands have parameters which follow the keyword. The available commands can be categorised by their purposes as follows:

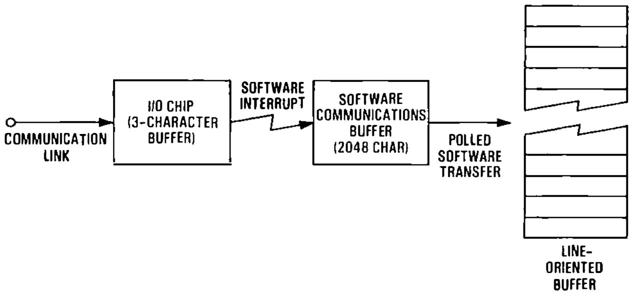


FIG. 4—Processing of data received from the remote computer

TABLE 1
Examples of Commands

Command	Effect
APPLY: <*filename*>	This causes a command file to be executed. Command files can be nested or chained. A variant of this command allows parameters to be passed to the command file.
LOG: <*filename*>	This opens a disc file log of all transactions with the remote computer.
PRINTER:	Turns the printer on.
SET: <*variable*> = <*value*>	This assigns a value to a variable.

(*a*) Specification of data source; for example, command-file processing and serial-file transmission.

(*b*) File creation; for example, logging and reception of serial data.

(*c*) Output control; for example, printer control and display options for incoming data.

(*d*) Transfer of control functions; for example, loops, GOTO, and file repetition.

(*e*) Conditional selection; for example, IF, ELSE and CASE constructs.

(*f*) Assignment; for example, use of variables, and setting flags and options.

(*g*) User-friendly facilities; for example, prompted data and menus.

Facilities for the Manipulation of Data

The user is allowed to define and manipulate variables, much as in conventional programming languages. In the program's internal representation of variables, however, values are always stored as data strings; only where the context demands it, are values converted to a pure numerical form. Variables can thus be used to hold, for example, complete lines of reply, or even commands. Facilities are provided for performing decimal and hexadecimal arithmetic, and for string processing operations. These facilities are used for processing data both entered from the keyboard and received from line. Variables and reply lines (and sub-strings of either) can be inserted anywhere in a command line by using a special notation which causes the replacement of the reference by its contents.

OPERATING MODES

The program can be configured to start up with one of a number of line protocols and modes of operation. The 2 principal modes are *direct mode* and *user-friendly mode.*

Direct Mode

Direct mode is characterised by the ability of the user to send keyboard inputs directly to the remote computer as well as supporting a number of local commands, processed only by the program. However, users are not restricted to typing in every command directly since command files of input can be scheduled for processing as if they had been typed at the terminal. In direct mode, all outputs from the remote computer are displayed on the terminal as they are received.The user can start and stop transaction logging to named files on disc and to the printer. The output is annotated so that the inputs can be distinguished from the outputs in later processing.

Direct mode is used extensively in testing applications, and reduces the time required for initialising, performing tests and analysing results. Users generally create subsequences of inputs which they store in small files. They can then bring all these sequences together by creating a master file which calls up these smaller files.

By taking advantage of the programmable protocols, design engineers at British Telecom Research Laboratories (BTRL), Martlesham Heath, have used the program to control a variety of experimental test equipment, thus reducing the effort involved in producing a documented set of tests. Final printed test documentation has been produced by inputting the logging files to a text-formatting system, thus reducing a number of manual overheads. At least 30 complete systems are now in daily use performing the above functions on a number of System X testing sites, and at locations in BTRL.

Serial file transfer is available in the direct mode, but is dependent to some extent on the facilities of the remote computer, in that the program effectively emulates a paper-tape reader for transferring data to the remote computer or a paper-tape punch for receiving data. This facility is not intended to replace other more sophisticated transfer protocols and does not include, for instance, any error checking. It has, however, proved to be very useful on many occasions when small files had to be transferred quickly, and when alternative means of transfer were simply not available.

User-Friendly Mode

In the user-friendly mode, the terminal keyboard and display do not appear to be connected directly to the remote computer. Instead, the processing of data received from the terminal and the line is under the sole control of command files.

Examples of constructs which are useful in the user-friendly mode are given in Table 2.

The user can enter information only when prompted by a command file. Input is either by selection of an item from a menu or in response to a question (prompt). Selection is made from a menu by moving a cursor target to the appropriate menu line. This movement can be either by single-step movements up or down or directly to the required item by entering the item number. The menu action does not take place until the RETURN key is pressed. This has been found to be an improvement on the traditional way of selecting a menu item, because the cursor target gives a visual feedback on the item that is being selected.

Where the user is expected to respond to a question, the program configures the keyboard so that only valid data is accepted. For example, if a numerical reply is expected, only the numerical keys are live; if any other key is pressed, then an error bleep is sounded. Numerical data can be further constrained to lie only in a certain range, so that if, for example, a number between 50 and 200 is required, then this range is checked before it affects the communication interface. Other types of data that may be selected are YES/NO decisions, telephone number formats, and hexadecimal numbers. A range of valid data lengths can be specified for these items.

TABLE 2
Examples of Useful Constructs in the User-Friendly Mode

Command	Effect
MENU: <*filename*>	This displays a menu defined in the specified file.
PROMPT: <*name*>,<*parameters*>	This is used to elicit responses from the user.
CASE: <*variable*> <*value 1*>: <*command 1*> <*value 2*>: <*command 2*> : : <*value n*>: <*command n*> ELSE: <*command*> ESAC:	This selects one command out of a set depending upon a match between the variable and the value. The matching can be on the basis of string or numerical equality.

When sufficient information about the user's wishes has been gathered, the program assembles a suitable command from data held in internal variables and sends it to the remote computer. The reply is awaited on a time-out basis. Reply time-outs can be varied for different commands, depending on the predicted length and speed of response expected. Often the user's wishes cannot be executed in a single command to the remote computer; in these cases the command files contain instructions about the series of commands to be sent. Usually this series is logically generated as progressive replies are received and analysed.

So a single request from the user of the terminal can result in many interrelated transactions between the microcomputer and the remote computer. Under these circumstances, a delay of several seconds can be encountered, particularly if communication is over a slow-speed modem link. In order to keep the man–machine interface as friendly as possible, a comfort indicator is presented on the screen. This reassures the user that processing is continuing, and gives a visual representation of the length of the waiting time predicted and what proportion of the wait is complete. The comfort indicator is event driven, and is designed to demand the minimum of processing power from the microprocessor.

The information presented to users is derived from the replies from the remote computer by using the logical operations (IF, ELSE etc.) or the powerful CASE construct described in Table 2. Abbreviated codes can be translated into full explanations, and user-friendly output screens can be generated on the terminal. Complex error messages from the remote computer system, which on many machines appear merely as numerical codes (for example, RUN ERROR 27), can be translated and presented in a more appropriate way, together with help about how to circumvent the error condition. The command files can even contain error trap routines which will attempt to recover from failed transactions.

In summary, the man–machine interface can be designed to be appropriate for the user regardless of the man–machine language of the remote computer.

FURTHER DEVELOPMENTS

The problem of lack of user-friendliness and consistency is becoming more common as computers are introduced into nearly every kind of work environment. It is becoming increasingly important that the method which people and computers use to communicate with each other is readily understandable to untrained users. Furthermore, the proliferation of computer terminals of different kinds in administration and other offices is creating new problems. In some cases, it is predicted that staff will have 3 computer systems to assist them in performing their jobs, and confusion is bound to arise in the operation of the computer systems, which will have man–machine interfaces of varying sophistication and modes of operation.

A possible solution may be found in the *front-ending* of these multiple computer systems with a translation system of the type described, based in the users' office and coupled to a switching system to select the service required. This could lead to a more consistent interface and, where electronic switching facilities are provided, to the possibility of performing multiple transactions on a number of differing databases which the user sees as a single operation.

Thus, the front-ending of one computer system by another for the purpose of achieving simple and consistent interfaces is likely to increase, and approaches similar to those described in this paper are likely to be increasingly common in the future.

Integrated Digital Access—A Step-by-Step Description of the Network Terminating Equipment

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UDC 621.394.4 : 621.395.74

British Telecom will introduce an integrated services digital network (ISDN) for its customers in 1984, and will market it under the name of integrated digital access. Customers will be provided with a network terminating equipment (NTE) to interface their data and voice terminals with the local exchange. This article gives a step-by-step guide to the rationale behind the internal structure of the NTE.

INTRODUCTION

In 1984, British Telecom (BT) plans to bring into service the initial installation of its integrated services digital network (ISDN). This network will provide customers with a variety of new services based upon 64 kbit/s switched circuits with access to the local exchange via an 80 kbit/s digital link over a conventional telephone line as shown in Fig. 1. This link, terminated at the customer's end by the network terminating equipment (NTE), is marketed by BT under the name of *integrated digital access* (IDA).

The overall structure and method of implementation of the ISDN are described in reference 1. This article concentrates on the NTE (Figs. 2 and 3 show two NTEs which will be available for the pilot service in 1984) and gives a simple step-by-step guide to the rationale behind its internal structure. The internal structure of the NTE is broken down into functional blocks and this guide begins by describing the functional block nearest to the local line, and progresses by adding further blocks until a complete NTE has been described.

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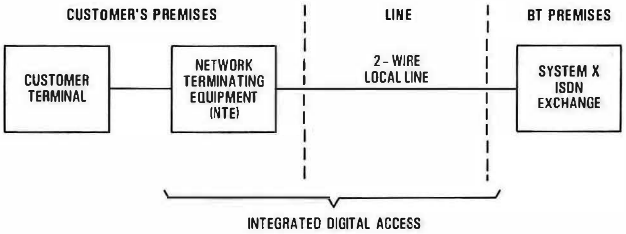


FIG. 1—Integrated digital access

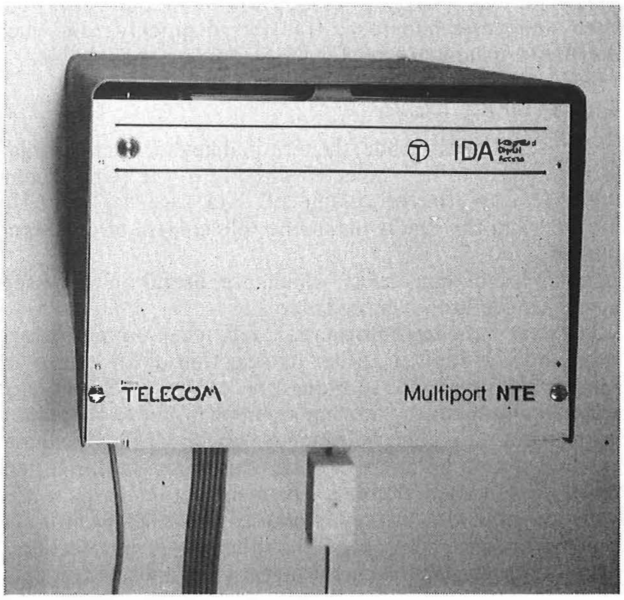


FIG. 3—Multiple-port NTE

FIG. 2—NTE with integral telephone

A particular feature of the NTE design is that it is based upon the layered structure outlined by the International Standards Organisation (ISO) in the open systems interconnection (OSI) model[2]. This layering enables functional blocks to be defined and enhanced without impact upon other functional blocks.

TRANSMISSION INTERFACING

The NTE communicates with the System X ISDN exchange over a duplex 80 kbit/s link by using an ordinary local cable pair. The 80 kbit/s line signals from the exchange are

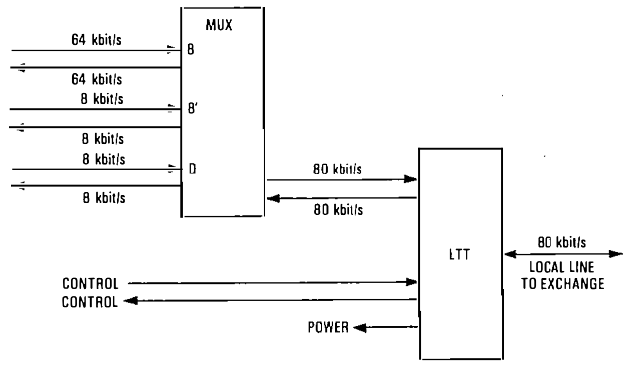


FIG. 4—Line transmission terminal

first intercepted within the NTE by the line transmission termination (LTT), as shown in Fig. 4.

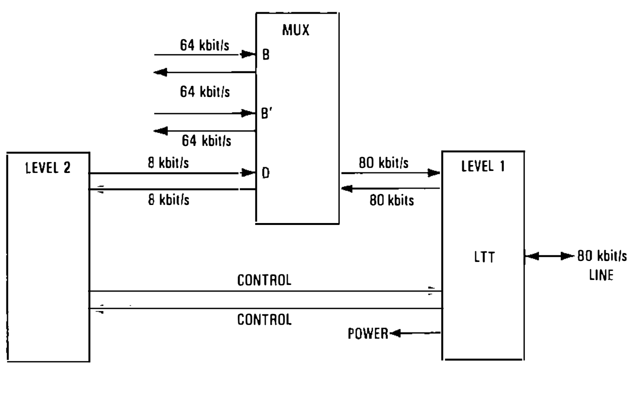
The LTT's functions correspond to the physical layer, or level 1 of the OSI model; level 1 being the means of communicating individual bits from place to place.

The LTT converts between the line signal and the logic levels of the internal interfaces. In the pilot service, transmission systems using either burst-mode or echo-cancellation techniques[3] will be available. The LTT derives positive and negative 5 V power supplies from the line, and this enables the NTE to provide limited facilities in the absence of locally provided mains power (the data-terminal interfaces are only mains powered). To avoid unnecessary use of exchange line power, and unnecessary crosstalk to other lines, the LTT can be powered down via the control lines.

The 80 kbit/s bit stream is then demultiplexed to provide a 64 kbit/s channel that may be used for A-law PCM encoded speech or for data, an 8 kbit/s channel for data and an 8 kbit/s signalling channel. The 64 kbit/s and 8 kbit/s data channels can be routed to independent destinations under the control of the 8 kbit/s signalling channel.

SIGNALLING SYSTEM

In order to implement a signalling system, it is necessary to impose some structure on the bit stream transported by level 1 and to use a protocol that overcomes any errors that may occur in the transmission system. Errors in transmission are likely to occur, for example, during transient fault conditions in the local network. The protocol to overcome such errors corresponds to the link layer or level 2 of the OSI model; its interconnection with the level 1 is portrayed



Note: B and B' refer to the 64 kbit/s and 8 kbit/s data channels respectively.
D refers to the signalling channel

FIG. 5—OSI model level 2 interconnection

FLAG	ADDRESS	CONTROL	INFORMATION	CRC	FLAG	etc.
01111110	1 or 2 bytes	1 byte	0 to 56 bytes	2 bytes	01111110	etc.

FIG. 6—HDLC format

in Fig. 5. There are two parts to level 2: formatting, and control. Although not necessarily the case, these are usually allocated primarily to hardware and firmware, respectively.

The format and the protocol are based upon the established procedures of high-level data link control (HDLC)[4]. Fig. 6 shows the format.

In this format, the flag acts as a unique delimiter and additional circuitry ensures that the flag pattern never occurs in the bits in the rest of the frame.

The address field is used to indicate whether the message is a command or a response, a signalling or maintenance message, and to which channel it refers (that is, 64 kbit/s or 8 kbit/s channel).

The control field is used to control the interchange and acknowledgement of level 2 messages.

The information field contains the signalling, or level 3 message. The whole purpose of the level 2 functions is to guarantee correct reception of this part of the message by the other end of the local transmission link.

The cyclic redundancy check (CRC) plays a major role in guaranteeing the reception of messages by detecting any errors that may occur during transmission. The CRC is formed at the transmitting end by calculation from the bits in the address, the control and the information fields by using the established procedures of HDLC. At the receiving end it is recalculated from the possibly erroneous received address, control and information bits. Only if the received and the recalculated CRCs are identical is the frame acknowledged. Complete frames are repeatedly transmitted until an acknowledgement of correct reception is received from the far end. This is referred to as a *compelled signalling system*, and with the CRC check gives a system which is immune to errors even when the error rate reaches one error per 1000 bits transmitted. With even poorer error rates, the probability of a message being corrupted is so high that, before enough time can be allowed to elapse for an uncorrupted message to get through, safeguarding time-outs will expire. It should be noted that this error checking is done only for the 8 kbit/s signalling channel. It is not done for the data channels, but left to the user to implement similar in-band procedures if necessary.

CALL CONTROL

The level 2 having provided a guaranteed transmission of the level 3 part (network layer of the OSI model) of the signalling message, it is appropriate to look at the level 3 call-control mechanism itself. Fig. 7 shows a block diagram of a terminal connected to the NTE via a terminal adapter. The channel selector enables the call to be routed by the call-control module to whichever channel (64 kbit/s or 8 kbit/s) is appropriate for the particular terminal.

Fig. 8 shows typical level 3 call-control sequences for a telephony call. It can be seen that, as far as the user is concerned, there is no difference in operating procedure between IDA and the current telephony network. However, there are major differences between the NTE-to-exchange signalling and the conventional telephone-to-exchange signalling. The mix of electrical signals used by a normal telephone (for example, loops, in-band tones and ringing current) is replaced by the level 3 messages which are carried as particular bit patterns in the information field of the level 2; for example, the *initial service request* (*ISR*) message is transmitted as shown in Fig. 9.

Other messages are encoded similarly by using unique bit patterns in byte 1, followed by qualifying parameters in the

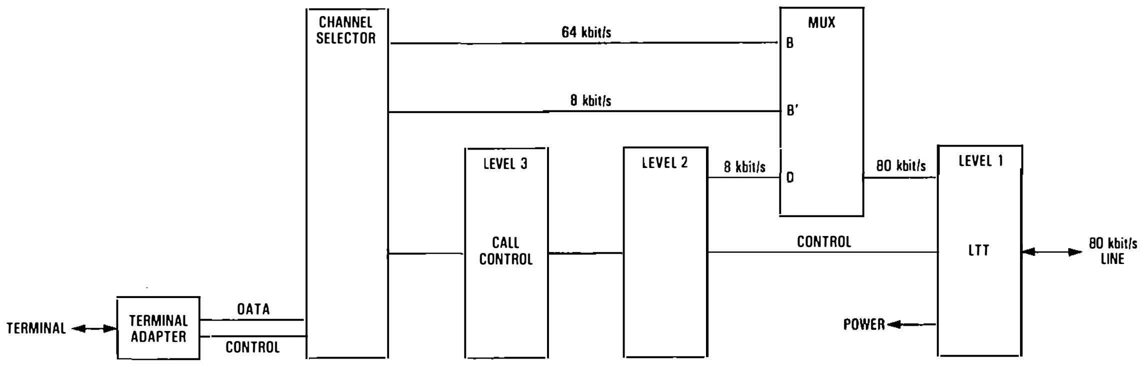


FIG. 7—Terminal interfacing

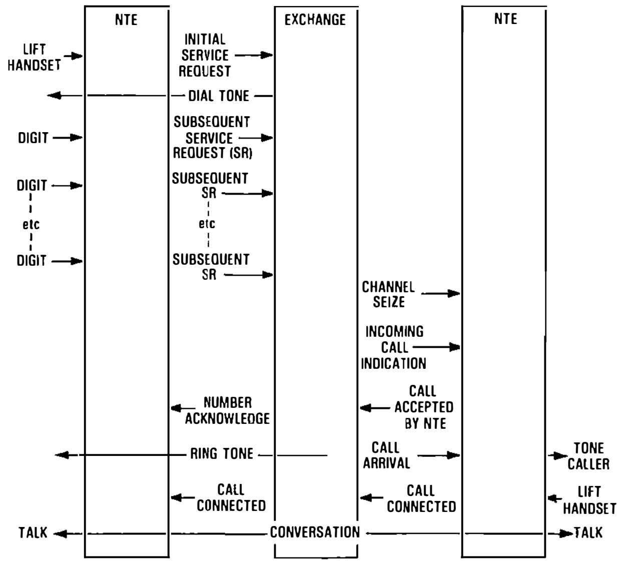


FIG. 8—Telephony call via ISDN

other bytes. It is now easy to see some of the benefits of using the OSI layering of functions, because new messages can be added in the future by the allocation of an appropriate bit pattern and meaning with no effect on the level 2 or level 1 definitions. This is unlike the current telephony network where almost any new message requires new electrical interface equipment at, in effect, level 1. For example, the addition of a subscriber's private meter has to be done by a variety of out-of-band signals which can be incompatible with other out-of-band services.

Although Fig. 8 shows in-band dial and ring tones, they are present only for compatibility with conventional telephony service as seen by the customer. They are not required for the correct functioning of the NTE since the user can press digits before receiving dial tone and the *number acknowledge* message duplicates the ring tone.

As shown in Fig. 9, the *ISR* generated as a result of the handset being lifted contains an indication that this is a telephony rather than a data call. This indication is refered to as the *service indicator code* (SIC) and it is used in 2 ways:

(*a*) by the exchange to determine whether an all-digital routeing is required (for telephony calls, it is possible to have analogue plant in circuit), and

(*b*) by the distant NTE, where it is delivered in the *incoming call indication* message so that the NTE can reject the call if it does not have (in this example) a telephony port.

After the NTE accepts the call, the exchange allocates a switch path and sends *call arrival* to the NTE so that the tone caller can be energised. When the user lifts the handset, a *call connected* message is sent back through the network, and the path is switched through; charging then begins and the users can begin conversation.

The user can set up data calls in a similar manner to that for telephony, but it is more appropriate for the data terminal itself to set up and control the call. A data terminal conforming to CCITT† Recommendation X21[5] achieves this by the use of its data and control wires in combination in defined simple sequences (for example, a *call request* corresponds to the data wire at 0 and the control wire ON).

Fig. 10 shows a typical message sequence chart for an X21 data call. The NTE maps the call control signals on the

†CCITT—International Telegraph and Telephone Consultative Committee

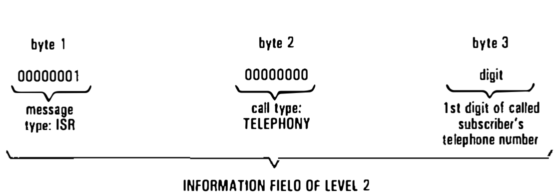


FIG. 9—*Initial service request* message

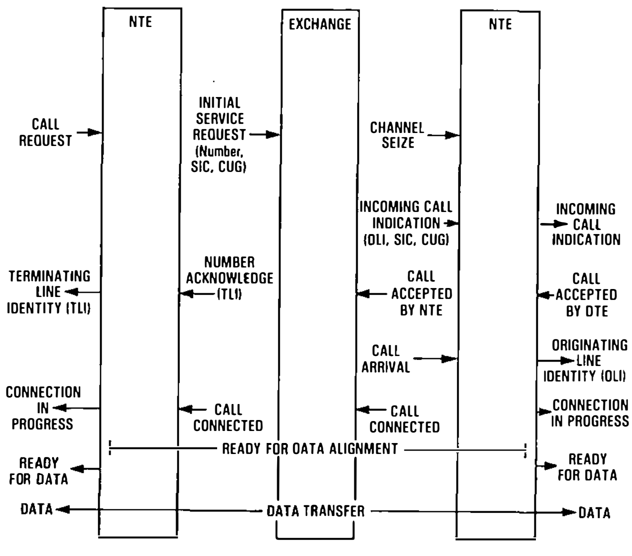


FIG. 10—Recomendation X21 data call

X21 interface to level 3 messages in the 8 kbit/s signalling channel and vice versa. Fig. 10 is broadly similar to Fig. 8 but with a few important additions. For a data call, the *initial service request* contains the complete directory number of the wanted NTE, together with the SIC and, if required, a closed-user-group identifier. For data calls, the SIC byte contains details of service type (for example, Facsimile, Teletex, slow-scan TV, or data), rate adaption (see below) and data rate (that is, asynchronous rates up to 9600 baud, or synchronous rates of 2·4, 4·8, 8·0, 9·6, 48 or 64 kbit/s). This SIC is delivered to the distant NTE, which can then alert a compatible terminal with an X21 *incoming call indication* or reject the call if the terminal is not compatible.

For a successful call, a *number acknowledge* message containing the terminating line identity (TLI—the directory number of the called NTE) is sent to the originating NTE. The TLI can be passed to the terminal as a check of correct routeing or it could be used to identify to which destination a call has been diverted by the distant user. Similarly, the distant NTE receives the originating line identity (OLI), which is the directory number of the originating NTE.

When *call connected* is received by the far exchange, the path is switched through. A ready-for-data alignment sequence involving in-band data between the NTEs is used to ensure that the *ready for data* message is not sent to the terminals until switch-through has definitely occurred. The alignment procedure also ensures that both terminals are sent *ready for data* in synchronism as required by CCITT Recommendation X21[5].

Other call control sequences exist to include call clearing and maintenance features[6].

RATE ADAPTION

At present, many terminals operate at data rates of 2·4, 4·8, 9·6 and 48 kbit/s as specified by the CCITT in Recommendation X1[7], and there is a need for adaption between these rates and the 64 kbit/s and 8 kbit/s rates of the bearer channels. Currently, the CCITT specify the '6+2' method[8] of rate adaption, and this method is shown in Fig. 11 for adaption from 48 kbit/s to 64 kbit/s. For rates lower than 48 kbit/s the data is reiterated up to 48 kbit/s; then the above scheme is used.

However, the 6+2 method of rate adaption is not suitable for adapting the 2·4 and 4·8 kbit/s rates into the 8 kbit/s channel. An 8+2 method (8 data-rate bits interleaved with a status and a framing bit) could be used, but the simple framing capability that is implicit in the 64 kbit/s scheme above does not exist. BT has therefore implemented a particular scheme to overcome this, and it is being discussed at CCITT as the basis of a new standard. The scheme is based upon a 5 octet frame as shown in Fig. 12.

	byte *N*	byte *N*+1	byte *N*+2	
48 kbit/s:	DDDDDD	DDDDDD	DDDDDD	etc...
64 kbit/s:	FDDDDDDS	FDDDDDDS	FDDDDDDS	etc...

Note: D is data bit,
S is the status bit (provided the carrier detect function of the modems), and
F is the framing bit to identify the start of an 8 bit frame on the bearer channel. This alternates 010101 etc. as a synchronisation pattern. (Within the ISDN, the framing is derived from the implicit byte timing available for the use of speech codecs.)

FIG. 11—Rate adaption to 64 kbit/s

Octet No:	0	1	2	3	4	
Bit No:	1				40	
8 kbit/s	00000000	1DDDDDDS	1DDDDDDS	1DDDDDDS	1DDDDDDS	etc...
4·8 kbit/s	frame alignment pattern	DDDDDD	DDDDDD	DDDDDD	DDDDDD	etc...

Note: D is the data bit, and
S is the status bit (provides the carrier detect function of modems)

FIG. 12—Rate Adaption to 8 kbit/s

The data is effectively pre-formatted into the 6+2 of Fig. 11 but with the framing bit set to 1. A number of 0s are inserted to pad out the frame, which, together with the following 1, provides an alignment pattern that cannot be imitated by user data.

Once the 8 kbit/s channel reaches the exchange it is reiterated to 64 kbit/s and routed through the network via normal 64 kbit/s switches. It can then be received by the NTE at the far end either on the 8 or the 64 kbit/s access channels.

COMPLETE NTE

Fig. 13 shows a complete functional block diagram of an NTE including rate adaption and a variety of terminal adapters. The terminal adapters convert between a variety of standard interfaces for the customer's equipment (for example, X21, X21*bis*, RS232C, telephony) to the internal interface of the NTE. If there are several different terminals connected to an NTE, the incoming calls can be routed to a particular terminal by means of the SIC; for example, a

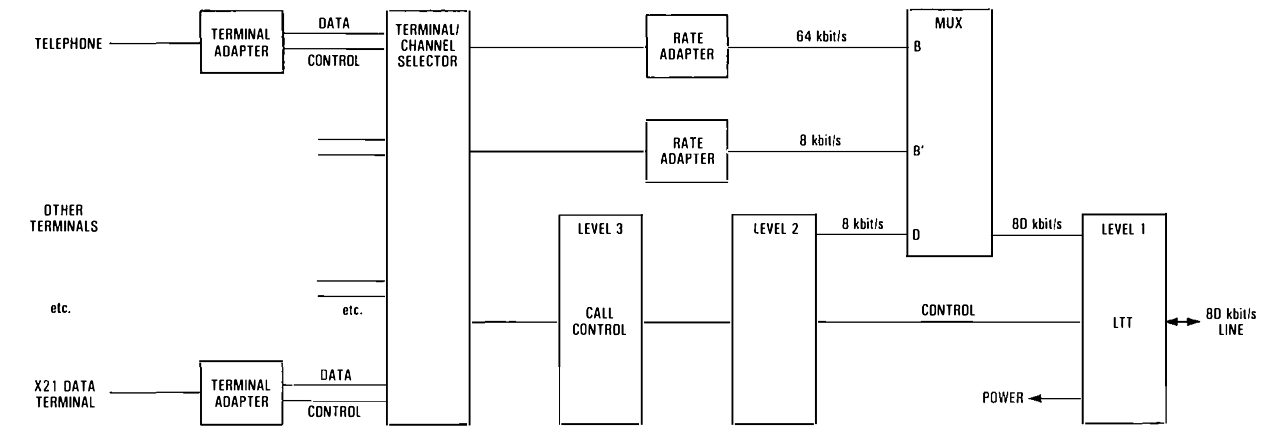


FIG. 13—Complete functional block diagram of an NTE

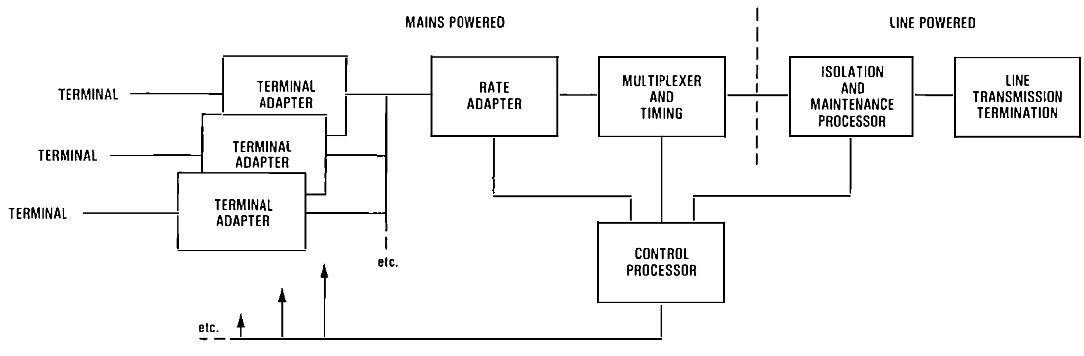


FIG. 14—Physical block diagram of a multiple-port NTE

voice call causes the tone caller to operate whereas a compatible data call causes the appropriate terminal to be alerted. The terminal adapter functions include an element of software to interface to the ISDN level 3 call control as well as to provide useful local facilities (for example, editing and storing frequently used numbers, or the ability to apply loops for maintenance purposes).

The blocks of Fig. 13 are purely functional and a practical realisation might combine several functions within one physical block; in particular, an NTE might use one microprocessor to perform several of the software functions as shown in Fig. 14.

A particular feature of the realisation of Fig. 14 is that there is a separate processor in the line-powered section. This processor is present solely to enable the exchange to conduct tests on the NTE when no mains power is present at the NTE. This is an essential requirement if the administration is to provide adequate diagnostics.

If off-the-shelf components presently available are used, then each of the blocks of Fig. 14 represents approximately a double-height Eurocard board (160 mm×233 mm). As the number of ISDN customers increases, it will be more economic to use uncommitted logic arrays (ULAs) and custom-built integrated circuits. This will bring the whole NTE down initially to perhaps 2 boards and eventually to one small board with consequent cost reductions. At present, the CCITT is attempting to define new terminal interfaces that are tailored to the ISDN's capabilities; this will remove the need for terminal adapters, and rate adapters within the NTE, and further reduce the cost of the NTE. However, it is unlikely that such standards will be available until at least 1988.

CONCLUSION

The above article has explained the need for, and the content of, each of the functional blocks within the NTEs for the BT ISDN pilot service. Even if it is built by using off-the-shelf components, an NTE can be constructed within a large telephone case or within a modem-like case. Work has already begun on developing ULAs to reduce the size and the cost of the next range of NTEs. Once new international standards have been agreed, a whole new range of NTEs and terminals will be developed, at which point costs will plummet because of the economies of scale that will be achieved in a potentially huge worldwide market.

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Telecommunications in the Rural Environment

J. R. POLLARD, M.A., C.ENG., F.I.E.E. †

UDC 621.39 (202)

Good communications are a vital aspect of a number of economic factors which have to be met if a country is to develop. Without rail, road or airline transportation, the hinterland of a large country cannot develop at all. In the absence of a postal service, business is hamstrung. In the absence of good telecommunications, modern industry—whether manufacturing or service—can hardly start to develop.

These requirements are of crucial importance in what has become known as the rural environment. This does not mean the meadowland found in the Midlands of England, but is a concept used to describe the type of terrain ranging from the South American pampas and valleys in mountain regions, to deserts, the Arctic tundra and snowfields, and many other varieties of geophysical environment. This article reviews the problems of providing modern telecommunications services in such regions of the world, and indicates how modern technology is making it increasingly possible to provide advanced telecommunications facilities even in areas of low population density, and widely scattered communities.

THE RURAL ENVIRONMENT

To British readers, the term *rural environment* conjures up pictures of rolling grasslands, copses, the occasional stream at the bottom of a valley, and other idyllic and pastoral scenes. Such regions have characteristically a population density that is usually fairly low; as a consequence distances between houses and other buildings tend to be very much longer than in the more closely populated urban areas. Such considerations apply with equal force where an environment is, by British standards, in more difficult terrain. In arid countries, for example, where thin scrub, stony plains and sandy deserts are to be found, population densities will be even lower, and communities even of small size are likely to be found only in the vicinity of an oasis.

Elsewhere in the world, for example in mountainous regions, small communities usually exist only in those parts of mountain valleys to which access can be obtained on foot or in suitably rugged wheeled vehicles.

Whether the region is based on lush meadowlands, rocky or sandy deserts, the unifying characteristic is that comparatively few people live in the territory and that they are relatively well spaced out. It follows, therefore, that telecommunications in these areas will be of a totally different character to those found in highly populated urban districts.

NATURE OF THE RURAL COMMUNICATIONS PROBLEM

Whatever terrain is concerned, it is clear that the most significant parameter defining the rural telecommunications problem is that the average population density is very low. In rural territories, it is quite common for a town to be of no more than some 200 people, and likely to be separated by many tens of kilometres from other similar towns, with many hamlets and individual dwellings scattered about between the towns. Much more widespread and scattered communities are likely to be found in terrain that is fertile enough for cattle raising, but where the annual rainfall is such that it can support a maximum cattle density of a few beasts per square kilometre rather than to the hectare. In these circumstances, communities become still smaller and distances vastly greater.

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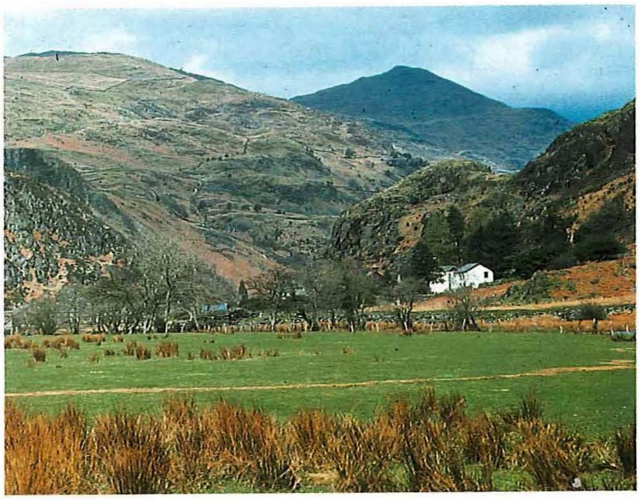


Typical mountain/valley terrain needing communications

Level of Service

The level of telecommunications service which is demanded by such low population densities and small communities makes it difficult to produce sufficient revenue to justify the provision of any communications service at all. The dilemma is a classic one. In the absence of modern telecommunications service, it is difficult to see how the region or territory can grow in population or effectiveness, and in the absence of a much larger demand, there is no financial inducement to invest in the provision of such a service.

These considerations have produced a long history of only primitive services being offered in the regions and territories concerned, extensive use of party lines, simple manual systems located in a farm kitchen and operated by the farmer's wife if she happens to be within earshot, and not available out of 'office hours'. The contrast between such rudimentary services and the needs of business in the urban environment is obvious. It is clearly essential to provide modern telecommunications services if such rural areas are to be acceptable for residential living, and even more so if the natural

Early rural communications—a wooden bicycle

resources of the region produce a potential for significant business development; for example, the availability of mineral or other resources.

Until comparatively recently, equipment to serve the needs of rural communities was extremely limited in its performance because of economic and other considerations. As already mentioned, many of the switchboards were simple skeleton manual, but after the Second World War there were substantial exports from the UK of extremely-simple small exchanges specifically aimed at the rural environment. Generally speaking, those exported from the UK employed 600-type and 3000-type relays with special tropical finishes, and similarly finished type-2 or type-3 uniselectors. These uniselectors were used equally as line finders, group selectors, and final selectors. Two or three-digit numbering schemes were used, with a stage-by-stage selection loosely corresponding to that employed in more conventional Strowger exchanges. The particular combination of relays, uniselectors and tropical finishes proved to be extremely reliable, regardless of the climate and the other conditions to which the equipment was subjected, and such systems introduced automatic telephone switching to very many sparsely populated areas. Among these were East and West Africa, isolated communities in Canada and elsewhere in North and South America, in and around the Gulf States in the Middle East and further towards the Orient. These systems were also used on many islands scattered over the oceans, and a very high proportion of the total supplied in this way are still in service, in many cases with well over 30 years of relatively fault-free operation in some of the most testing climates in the world.

During the 1970s such networks were being extended by the addition of rural crossbar exchanges developed from the TXK1 (Plessey 5005) system.

Many of these exchanges were in very remote sites, many kilometres from the nearest town which, in any case, mostly contained perhaps 100 or 200 people. One particular installation was at the far end of a 110 km single-width road, which was worked on the basis of west-bound travel using the road on odd days and east-bound travel using it on even days. In the event of a breakdown, which fortunately was rare, telephone maintenance staff had to obtain a permit to travel the wrong way down this road.

Elsewhere in the world, such installations were often made on remote islands, and in the event of a breakdown it was sometimes necessary to wait for favourable weather before a crossing could be made by small boat to the island concerned to restore telephone service.

One of the many ingenious solutions to these particular problems served the island of Herm in the Channel Islands off the UK coast for very many years. Here, the original installation, planned for an ultimate capacity of 17 telephone subscribers, was estimated to produce a revenue of £85 each quarter. Thus, it is clear that the capital cost of the equipment and of the installation cabling has to be commensurate with a low total annual revenue, and this almost more than anything illustrates the general problem of the rural community.

Main Exchange Modernisation

By the 1970s, much more modern main exchange systems were becoming available, but many of these had high initial costs almost independent of size, because of the inclusion of common control, or stored-program control (SPC), in association with either modern analogue or digital switching networks.

In some cases, such systems can be installed in nearby towns, and service given to the very low population density by the use of remote concentrator switches parented on the distant central office.

However, in most parts of the world, the distances involved are such that this method of operation is unattractive, especially in view of the total loss of service that would result from the link to the parent system becoming unserviceable, or being cut.

Early experience with digital systems, and in general with SPC systems, whether digital or analogue, tended to indicate that they were most attractive for use in large sizes, and in high-traffic versions, because the high start-up cost of the basic processor complex implied a per-line cost that made the resulting exchange unattractive except in larger-sized versions. Inevitably, the development of microprocessors and storage systems, speeded as it was by the mass production of computers of substantial power and available at hobby prices, meant that the cost of control complexes would fall rapidly. However, the basic principles of security which are implicit in any public telecommunications service tend to reduce the probability of such rapid falls in the cost of provision of control complexes as would be found in simple microprocessor machines. Nevertheless, at least in theory, the way was open for a breakthrough in system costs to enable small low-cost digital switches with full SPC to become available to complement the large switches under development, or already being produced as part of the electronic switching system program under development in virtually every corner of the world.

British successes with the early electronic exchanges (TXE), leading to proprietary microprocessor versions of TXE2 and TXE4A, the successor to TXE4, both showed

Equipment being delivered to a pre-fabricated building for a rural network that the fall in costs of electronic control systems could be made to have a sufficient impact on the total-system cost to make extremely small systems (100 lines or below) economic in reed-switch microprocessor-control analogue exchange systems. Small quantities of such systems were, in fact, ordered from 2 manufacturers, but by this time it was clear that digital switching had a potential to overtake analogue switching in the small exchange field as well as more generally for larger sizes, transit centres, etc.

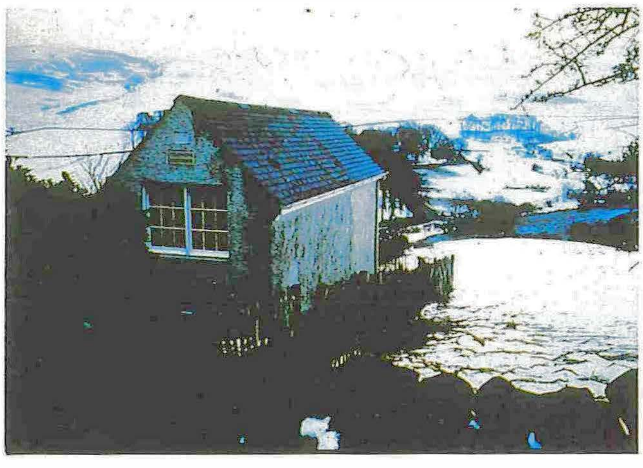
Introduction of Digital Systems

Two things had to be successfully accomplished in order to produce an economically-attractive small digital SPC exchange. The first of these, previously noted, was the rapidly decreasing cost of processing power and memory, leading to much lower initial costs for processing systems of modest total processing power. The second was the increasing availability of custom-designed large-scale integration chips which could themselves embody a substantial number of the functions of the line-circuit end of the switching system. Traditionally, the line circuit in digital and time-division switching systems has always been a major cost problem, since every component in the line circuit is provided on a one-per-line basis and, therefore, component count, printed-wiring board mounting space, and general circuit complexity must all be reduced by substantial proportions in order to realise an economic system.

UK progress in large-scale integration custom and semi-custom design versions soon reached the stage where the over 40 components per line, which would be typical of a digital line circuit a few years ago, were reduced by almost an order of magnitude with a concentration of more and more logic and signal processing power onto fewer and fewer components of individually rapidly growing complexity.

This trend of lower processing costs and substantial reduction in line circuit costs had already provided a number of modern PABX systems approved for connection to the public network in the UK, and available from several UK manufacturers. One of these, Customer Digital Switching System No. 1 (CDSS1), had been developed by British Telecom Research Laboratories at Martlesham, and put into industrial engineering processes for subsequent production by Plessey and GEC, and the technical and economic success of this led to the realisation that exactly similar principles could be used to create a particularly cost effective rural switching system, which by analogy with earlier systems became known as *Unit Exchange Digital No. 5* (UXD5).

The principal distinction between UXD5 and competing systems available from overseas manufacturers is that UXD5 can be made in very small sizes, with a very low minimum start-up cost; this is achieved by an inherently-economic design and, of course, by being associated with volume production of similar components and circuit boards for the much larger needs of the PABX market.



Building housing an early UXD5 installation in the Scottish Highlands

For the first time, the emergence of UXD5 as a serious production system prepared the way for the introduction of entirely new standards of service in the low-traffic-density highly-dispersed subscriber area characterised by rural networks. Whereas most SPC systems with digital switching have an initial cost that makes them uneconomic except for comparatively large installations, UXD5 is attractive economically because it is a single-rack system that serves some 100 subscribers. In this role it is clearly going to have a very important part to play in the penetration of new services into the rural network.

The Signalling and New Services Problem

One of the difficulties with older electromechanical systems was that they were limited to decadic impulse signalling, and correspondingly were not able to offer anything in the way of services other than the most basic communications operations. In addition, extensive re-design was needed to install such systems in territories requiring other than decadic signalling between exchanges. In complete contrast, UXD5 offers a complete range of services similar in application and use, and just as attractive as the services offered in large urban SPC digital switches. The consequences of this to possible business developments in the rural environment cannot be over emphasised, since the availability of a truly digital path between end user and the public network greatly facilitates data and a large number of other supplementary services.

In many respects, then, UXD5 and its derivatives and successors represent an important breakthrough in the provision of modern telecommunications resources in the rural environment.

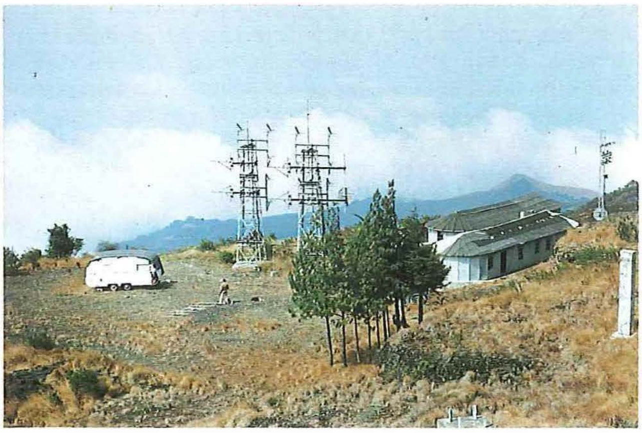
It is, of course, necessary to consider the other classic bogies encountered in the rural environment—those of how to maintain the equipment economically, and how to provide appropriate power to operate such a system. In addition, there are the traditional environmental problems of wide ranges of temperature and humidity, and in tropical countries the possibility of insect and animal attack.

Maintenance

The problem of system maintenance is greatly facilitated by the availability of an intelligent processing system in the rural switch itself. As a result of this, a maintenance control centre that may be at a considerable distance away can interrogate the rural switching system, determine its operating parameters, analyse any faults which may have arisen, and study the impact of these faults on the traffic handling capacity of the remaining healthy part of the network.

The Power Problem

It is less easy to see how to deal with the very difficult problem of power supply. Generally speaking, if there is enough of a community to justify any sort of telephone service, there will be the possibility of some power supplies existing, even though these may be of limited performance and limited availability in terms of operating hours. At least the possibility exists that some kind of power will be available at the switching centre in many, if not all, cases. However, this is not universally true, and power remains both in the short and long term a considerable problem to the establishment of telecommunications services in rural environments. Progress has been made with both wind- and solar-powered generators, but the capital cost of these in relation to the need to provide a guaranteed minimum of power over sustained periods of time does not make them,

Rural installations in terrain requiring entirely radio links to outside networks

at present, economically feasible. Environmental and social considerations have so far excluded the use of very small nuclear power supplies. The only contribution that has been realised is that the use of ever increasing amounts of large-scale integration in the switching and control areas of such systems as UXD5 is progressively driving down the power which is required, thus making it both easier to provide such systems in remote locations and more economic to provide storage-battery capacity to bridge gaps in the availability of power; for example, in the hours of darkness, if solar cells were to be used.

The question of how to make the equipment immune from attack by insects and animals concerns the construction of suitable enclosures. The conditions inside these enclosures can commonly be much more adverse in terms of temperature range for modern semiconductor equipments than they could have been for older electromechanical systems, which are in any event particularly vulnerable to contamination by airborne dust or grit particles.

TRANSMISSION LINKS

The one remaining problem not so far dealt with is the question of how such a rural switch can be linked to the outside world. A large variety of solutions can be proposed to this problem; which of them is attractive in a particular case depends largely on local circumstances. Subject to considerations of distance and problems associated with the terrain, conventional cable circuits, with buried or aerial cable, using most probably pulse-code modulation systems for transmission, will meet the majority of cases. In some instances, especially when long routes are involved, it may be desirable to use optical-fibre transmission as an alternative in view of the much longer lengths that can be spanned without intermediate repeaters for such systems being needed.

There will, of course, be many instances where the rural switch is located so remotely, or so inaccessibly, from the nearest larger community that radio offers the only practical solution. Provided that the path can be accomplished in a single hop, this imposes no special further limitations, but serious problems arise if a multi-hop path is involved, in view of the difficulty of providing power at the intermediate repeater stations.

Many installations have been made in parts of the world in which a network in one relatively inaccessible valley is connected to a parent city in the next valley by the use of a passive reflector as part of the transmission path for the radio system concerned; but here again there are obvious difficulties for the longer paths.

A still further alternative, where power is to be brought to the rural community by overhead power cables, lies in the use of optical-fibre cables associated with the power system conductors. The high insulation value of the optical-fibre light guide medium makes it possible to have such optical fibres made up as part of a power cable bundle, so that communications channels can be carried on the same physical circuit element as the power which, in part at any rate, will be used to operate the equipment at the distant end.

CONCLUSION

It still remains to be seen whether all the factors will combine sufficiently well for it to become practicable to offer modern communications resources to any isolated user, or small community, however remote. There must always be some lingering doubts about the practicability of modern communications to a user several hundred kilometres away from his next nearest users, and there are many parts of the world where this kind of geographical spread is still found. However, the remarks above indicate that British telecommunications manufacturers have continued, as they did in the past, to treat the telecommunications problems of the rural environment very seriously indeed, and to have solutions emerging into practical production which will enable the most modern classes and the most advanced services of telecommunications facilities to be made available to people who in previous generations would have counted themselves fortunate to have an occasional postal delivery.

Key Systems—The Hybrid Concept

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For many years the telecommunications requirements of small business users has, in general, been served by multi-conductor systems that are relatively inflexible and have limited facilities. However, the advent of low-cost electronic components has enabled sophisticated stored-program control concepts to be applied to the smallest of office systems. This article briefly outlines the evolution of key systems and shows how these developments in electronics have made available highly flexible systems at competitive prices.

INTRODUCTION

Modern hybrid systems and electronic key systems are rapidly replacing many types of outdated switching systems for the small business user, and in so doing are offering the user a more efficient means of communication. The market is very large and competition fierce; key systems must cater for the needs of different territories, different market sectors, and individual customer requirements.

In defining a hybrid system, it is helpful first of all to try and clarify what is meant by the term *key systems*. One definition is that the term refers to small private switching systems which essentially are designed to work without an operator, and which enable the users to communicate with each other and the outside world by means of specialised telephone terminals. These terminals have keys (that is press buttons), to enable functions and facilities, especially line access, to be activated. Many key systems also have the ability to use industry-standard telephones where the special functions can be accessed by dial-up codes.

Unfortunately, this definition is somewhat blurred by the fact that many key systems allow for an operator position, and offer facilities that make them indistinguishable from a PABX. These systems are now tending to be referred to as *hybrid systems*. Another blurring fact is that many systems which were conceived as PABXs using conventional telephone instruments are now offering *facility* terminals with keys. These keys are used to call up functions just as in key systems. The term *key system* was coined in the USA where the systems were first introduced. The term is not widely used in Europe—for example, British Telecom use the term *call connect system*.

EVOLUTION OF KEY SYSTEMS

Why are key systems necessary? It is helpful to look at those types of business whose telecommunications needs are not served by direct exchange lines on the one hand, or by a full-blown PABX on the other. Some typical users of a key system are:

(*a*) travel agency,
(*b*) mail-order office,
(*c*) enquiry office,
(*d*) hotel/motel,
(*e*) solicitors office, and
(*f*) self-contained department within a large organisation.

All these users need a system which can handle quite high levels of traffic with a fairly small number of extensions. The first 3 types of environment have very different needs from the last three in that the former's traffic will be very largely incoming calls. Hence there is a need for a system in which any user can answer an incoming call without operator intervention. Other requirements are that users should be able to hold calls for enquiry and transfer calls to another user.

It was to satisfy this need that the key system was developed. Early systems were electromechanical, and exchange lines occupied dedicated keys; usually some form of lamp indication was built-in to facilitate system use.

Early and Existing Systems

An example of this type of system in the UK is the key-and-lamp system. This system enables any of a number of telephones to be connected up to one of a group of circuits, these being exchange lines, PABX extensions, or private circuits, by means of a unit connected to each telephone. One key per circuit is used to either HOLD or SPEAK on the circuit, and an associated lamp is used to indicate the circuit status. Problems with this type of system are that it does not allow internal communication between users, and that the installation requires bulky multiwire cabling in between units. Nevertheless, the system satisfies the requirements of a large proportion of users.

A system which overcomes some of these problems is the house exchange system (HES). This constitutes a large proportion of the installed business systems in the UK. As an example, consider the HES3 introduced in the early-1960s; this combined the facilities provided by an extension plan with those of a small PBX. Users can select for themselves, by means of press-buttons, the required facility. These facilities include internal communication, exchange

10-line key-and-lamp unit

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or private-line access, internal conference calls, night service, and call transfer. Its limitations, however, include the lack of flexibility, and the need for multiple cabling, a main station requiring a minimum of 17 conductors.

These types of system are expensive to install, and have very limited growth capacity. Early American systems were also electromechanical in nature, and used hard-wired logic for control, and multiwire cabling. An example is the Western Electric Comkey 416, which is still being installed at the rate of more than 80 000 systems per year. This system allows for up to 4 exchange lines and 16 terminals. Terminals have up to 11 keys, and are connected to the common equipment by 25-pair cabling.

IMPACT OF ELECTRONICS

The advent of low-cost electronic components, especially microprocessors and other large-scale integration (LSI) components, is rapidly changing the key-systems scene. The use of electronics in key systems has brought improvements in communications efficiency by offering greater flexibility, and facilities which were not available in earlier equipment.

At first, electronic key systems were more expensive than electromechanical/wired-logic systems. Over recent years, though, electronic component prices have tended to fall, thus eroding this price differential to the point where, using a price/performance comparison, the electronic systems offer the user much more for his money.

MODERN HYBRID SYSTEMS

Examples of a modern hybrid system are the TMC KBX range of telephone systems. This includes the KBX10 and the KBX100, available in the UK from British Telecom under the name *Ensign* and *Herald*, respectively. The primary market sector for the Herald is business users requiring up to about 40–50 extensions and up to about 20 exchange or private lines. It is a solid-state stored-program controlled switching system with extreme flexibility of operation. The system consists of a central control equipment connected to multi-key terminals or industry-standard telephones, requiring 2 pairs or one pair respectively.

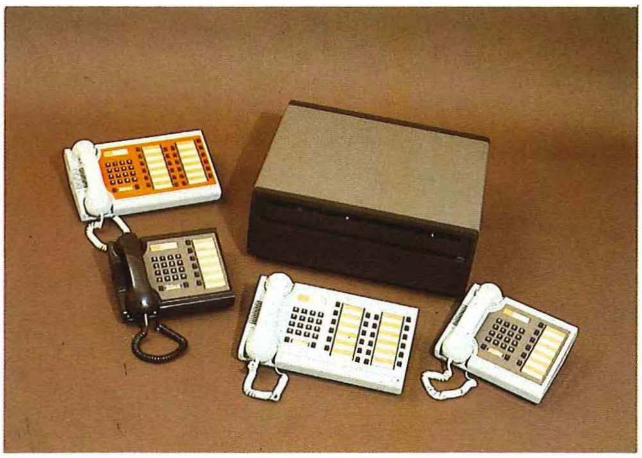
System control is by means of a single microprocessor whose executive program is stored in mask read-only memory (ROM). Random-access memory (RAM) is used for state and data storage, and the customer and administration database is stored in electrically-alterable ROM (EAROM). It is this last type of memory which allows much of the system's flexibility. Every device in the system, whether it be a multi-key terminal or an exchange line, has its parameters stored there. The memory is non-volatile, and can be altered by the customer or the administration. Hence, there is no need for battery back-up (in the event of power-failure, direct exchange line operation is granted to selected extensions).

Note: The Ensign is a compact system with up to 12 dual-purpose ports providing a maximum of 6 exchange lines or 10 extensions. The system can be configured as a key system or as a PBX with or without attendant position

KBX10 (Ensign) control unit showing wall-mounted book-type construction

User-Friendly

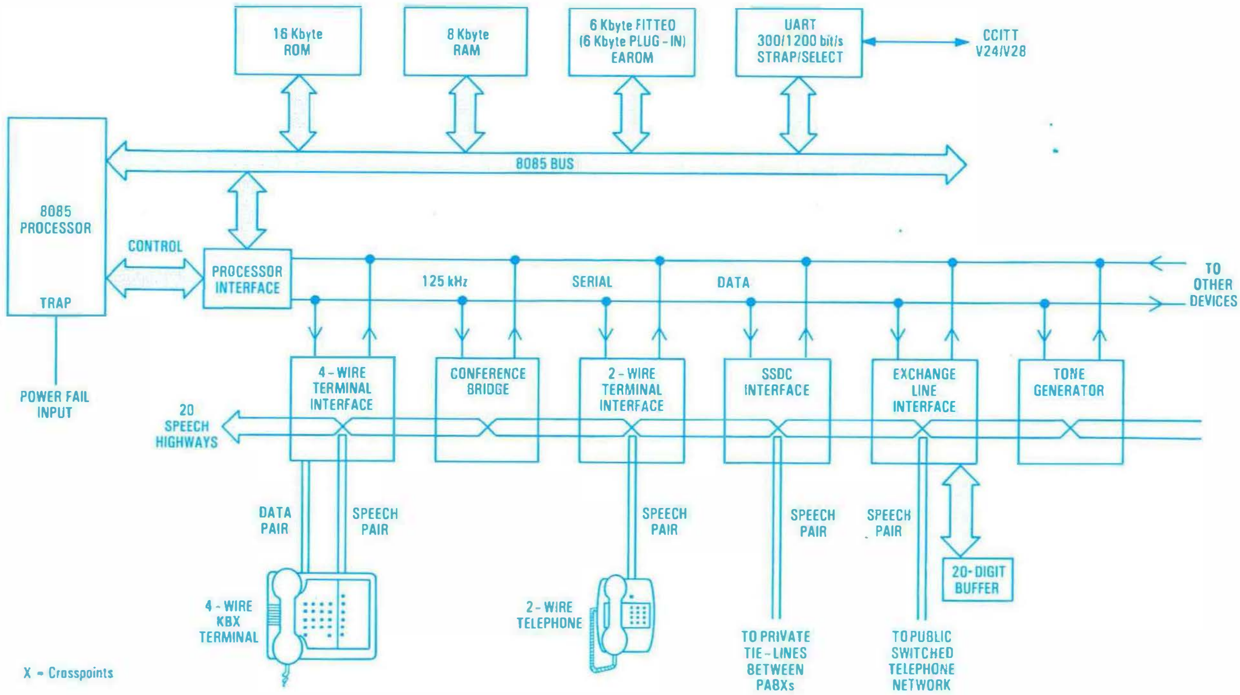
Two sizes of multi-key terminal are available, one having 8 programmable keys, and the other 26. In addition, each



The Herald call-connect system showing the central control unit and multi-key terminals

Note: Modern electronic press-button telephones (with loop-disconnect (LD) or multi-frequency (MF) signalling) can be used with key systems as well as the multi-key terminals

Standard 2-wire press-button telephone



Block diagram of the KBX100 (Herald) system

terminal has the standard 12-button keypad with digits 0–9 and * and #, and 4 fixed-function keys for the PBX RECALL, TRANSMIT PROGRAM, and HOLD features. The programmable keys each have a light-emitting diode (LED) situated alongside it which is used to indicate line or facility activation status. The administration can program functions and facilities against these programmable keys (for example, line access, divert, conference), and the user can program internal extensions to allow direct station calling, and external repertory dial numbers. The meaning of each key is stored in the central unit's EAROM, and not in the terminal, and thus allows simple replacement for faulty terminals.

Facilities

A full range of user facilities is provided. The system may be configured to suit the needs of the majority of small business users; for example, as a PBX answering system, executive/secretarial system, or automatic call distribution system, or indeed combinations of these modes.

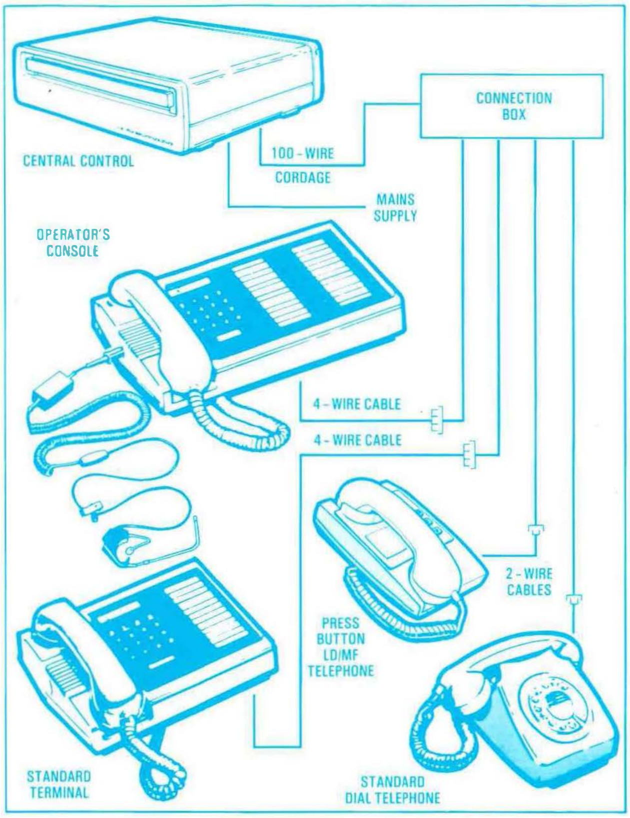
The facilities include executive override (or intrusion), conference, call diversion, sounder and lamp control, repertory dialling, repeat last number, and hold and transfer. These are accessible by means of programmed keys on terminals, but for users of standard-telephones they are accessed by means of dial-up codes.

Installation

Installation is aided by means of a program running interactively on a microcomputer located at a regional base. Starting from forms listing the customer's requirements, the customer database is built up in the system's memory by the program guiding the operator through a series of question-and-answer sessions. At this stage, features such as class-of-service (governing intrude priority) and call barring, are entered. Finally, the database is stored on a floppy disc,

General-purpose terminal for use with the Herald system

Low-capacity terminal that can be used with either the Herald or the Ensign systems



Typical system arrangements for the Herald

Herald central control unit (B version)

and several sets of documentation are printed, including a list of sub-unit requirements, a wiring schedule for the main distribution frame, and individual terminal labels.

Once the system is assembled, the same microcomputer is used to download the system from the floppy disc. Thus a record of each installation's database is maintained centrally. Modifications to the installation can easily be made by using the same program, and in fact the system can be downloaded remotely via the public switched telephone network (PSTN).

The KBX100 System's serial data link used in the downloading process can also be put to other uses, including device parking for maintenance, system diagnostics, and call logging data collection.

An enhanced version of the KBX100 is currently under development which will add considerably to the flexibility of the system. There will be a totally flexible numbering scheme whereby the user can define access codes and extension numbering (for example, for hotel applications). Other features include a 'self-programming' capability which allows the user to initialise and modify his database without the need for external equipment, and the programming of facilities from terminals and from the optional operator's console.

CONCLUSION

Hybrid systems are now being increasingly used in smaller businesses and professional groups, and in larger concerns they will frequently be found in use providing supplementary facilities behind a PBX, improving communications with a department. The systems use a mixture of special key terminals and industry-standard telephones (both loop-disconnect and multi-frequency (MF4) signalling), and are configured in many ways to suit the specific needs of the individual user.

Book Reviews

Communication Control in Computer Networks. Josef Puzmen and Radoslav Pořízek. John Wiley & Sons Ltd. 296pp. 135 ills. £13·20.

This is a very interesting and useful volume which deals with the subject of communications control of computer networks in a broad way. The authors seek to introduce the general concepts of control of networks and the problems which need to be solved and, as the book unfolds, to describe solutions and the methods by which solutions can be and have been sought.

Although the book takes account of much academic material in its approach to the subjects covered, it is very readable, and forms a good introduction to communication control. The individual items of subject matter have been drawn from many sources and placed in a position of perspective in relation to the whole. Eight appendices to the subject, which explain the derivation and relevance of particular international standards encompassed, have also been included.

The main subjects are covered in 4 parts with 20 chapters containing 84 subject subdivisions; bibliographical notes are given for each chapter.

The main subjects covered are: distributed processing networks, communication control, communication functions and communications protocols.

A fairly extensive alphabetical subject index is given at the end of the book, which is indexed mainly on the basis of commonly applied terms.

Of the 295 bibliographical references given, about 35 appear to be available only in their original languages of Russian, Polish and Slovak, which are amongst those less likely to be understood by engineers whose mother tongue is English. However, this limitation, if it represents a limitation, is not likely to affect the ordinary technically-minded reader seeking a good insight into the subject, but perhaps the expert who wishes to probe more deeply into the specialised fundamentals concerned.

Because the book covers a wide scope, it would be very lengthy to attempt to review the subject matter covered in any detail. Briefly, in essence it is a work which explains networks from their component parts to their whole; the aims and needs of data transmission (amongst other things); and the roles played by communication protocol in knitting together the features of networks and the requirements for data transmission.

This book is recommended reading for those seeking to expand their general awareness of the needs for machine and network protocol in data communication, and the considerations taken into account in network topology etc. The substantial number of references given could be very useful to those wishing to enter deeply into particular aspects of the subjects covered.

G. COMBER

Essential Electronics, an A to Z guide. George Loveday. Pitman Books Ltd. vi + 257pp. £5·59.

The title of this book does not immediately reveal that it is in essence a cross between an encyclopaedia and a dictionary of electronics. Just over 200 separate entries are included in alphabetical order, and these cover the whole range of electronics from the humble fuse to microprocessors. The range of topics covered is wide and the author clearly states that the list is essentially a personal one based on his own experience. In fact, no book nowadays could cover every subject in electronics, and the author clearly had to limit his choice otherwise the book would have become unmanageable in size. He has, for instance, completely omitted the subject of microwaves, which could have led to microwave sources and detectors, aerials (which are omitted for any frequency), waveguides, radar etc. In general, though not exclusively, he has concentrated on circuit-type electronics and electronic devices, though items such as modulation are covered. What is perhaps more surprising than the general omissions are the inconsistent omissions—why for instance does *CMOS* appear in the contents list but not *NMOS*, *PMOS* or *MOS*? (Though *MOSFET* is to be found referred to under *Field Effect Transistor*.) Despite those omissions, which are inevitable in a book covering such a wide subject, the author's choice seems sensible for a book of this size.

A further problem with the book is that it seems to attempt to be 'all things to all men'. At a fundamental level the author covers definitions of terms such as *ampere* and *semiconductor theory*. However, the treatment of these subjects is brief and can lead to errors by omission. For instance, in the section on semiconductor theory only 2 semiconductors are mentioned—silicon and germanium—with no reference to the fact that others exist. Yet in the section on opto-electronics, gallium arsenide and other similar compounds are introduced as semiconductor materials for LEDs (strangely, lasers are not mentioned). This discrepancy between the 2 entries could well cause confusion.

The author seems much more at home, however, on the more practical entries; in particular, on entries concerning aspects of circuit techniques. Such entries are well illustrated with example circuits, each carefully characterised with full specification of components and current and voltage values. However, although these circuits are interesting and useful, is this the source for looking up detailed circuitry for, say, different types of alarm circuit, or speed-control circuitry for AC or DC motors? In this respect the author has put too much detail into some subjects where the space could perhaps have been better used for other subjects.

Aside from the nature and content of the entries, a major criticism of the book must be its lack of an index. The contents list is merely the alphabetical list of entries and is effectively redundant. The cross-referencing from one entry to others is good, but the difficulty is finding the correct entry. To take one example: under *Johnson Counter* the counter is referred to as a 'twisted ring counter or walking code counter'; yet, as neither of these terms appears in the contents list, anyone not knowing the alternative name would be unable to find out about the counter. A book such as this ought to have an index; without one it is much less effective than it could be.

In summary, the explanations given in the book are clear, concise and well illustrated. If the subject a reader is looking for is in the contents list, the book provides a useful quick reference. However, the lack of an index and the inevitable omission of several areas of electronics means that the book's usefulness is rather limited.

J. R. GRIERSON

Communications Cables and Transmission Systems (Second, Revised Edition). Werner Schubert. Siemens Aktiengesellscaft. 224pp. 35 ills. £21·40.

This book is of German origin. The chapters on cable design, transmission engineering and theory are a useful reference for practising engineers who already have a basic knowledge of the alternative designs of telecommunications cables used in the UK and who can recognise the differences. The fundamental information on materials and techniques used to make cables is accurate, but is built around codes and regulations applied in the author's country. If the concept of a cable catalogue can be put aside, the reader will find the explanations interesting and the style easy to follow. While it is not the purpose of the book, it is a pity there is an absence of references other than to German Industrial Standards and to the types of cables specified for German-based clients.

G. BARTLETT

System X: The Operator Services System

M. A. PASHLEY †

UDC 621.395.34 : 654.06

The System X operator services system is a highly-flexible system that is able to support a number of network configurations, including traffic from non-System X exchanges. This article describes how advances in technology have been exploited to enable considerable improvements to be made to the operator service, and outlines a typical call set-up procedure.

INTRODUCTION

This article describes the System X operator services system (OSS), which is being developed at a time of great technological advance and varying social needs. Furthermore, the traditional role of the telephone operator is changing significantly. Technology has been responsible for much of the change but, far from eliminating the need for the operator, it may be exploited to improve the service considerably. The OSS achieves that objective. It enables an administration to place greater emphasis on customer satisfaction, helps counteract public disquiet about the inhuman face of technology, provides for the introduction of new facilities, and satisfies public expectation and the desire of the administration to improve service.

For the operator, the system provides more variety, a better working environment and the elimination of many tedious and time-consuming tasks. For the customer, the OSS offers new facilities, greater efficiency and the promise of a more personal service. For the administration, the system provides a wealth of management features, compatibility with System X digital exchanges, the freedom to locate operator units remote from the exchange and a significant improvement in performance.

NETWORK CONFIGURATION AND SYSTEM ARCHITECTURE

The OSS currently under development is an extension to the range of System X exchanges and offers a complete range of facilities for operator services. The design fully exploits recent advances in technology, stored-program control and the digital network to achieve a highly-flexible operator system that can evolve to meet future requirements.

Because of its modular structure and total compatibilty with the range of basic System X subsystems, the OSS can be realised in a variety of ways. Operators can be up to 1000 km away from their associated control equipment, and a number of different network configurations can be supported. The control equipment can be provided as any one of the following options:

(*a*) a stand-alone unit with its own dedicated switching, control and interworking equipment;

(*b*) a unit which is hosted on a System X local exchange, using that exchange for switching and interworking and, if necessary, sharing common routes and interworking equipment with that exchange; or

(*c*) a unit which is hosted on a System X trunk exchange, digital main switching unit (DMSU), or international exchange, using that exchange as in (*b*) above.

Options (*b*) and (*c*) substantially reduce the implementation costs of the system and network, especially if common routes are used for subscriber and operator traffic. The cost of the OSS hardware in the host exchange is small compared with the total cost of the operator consoles.

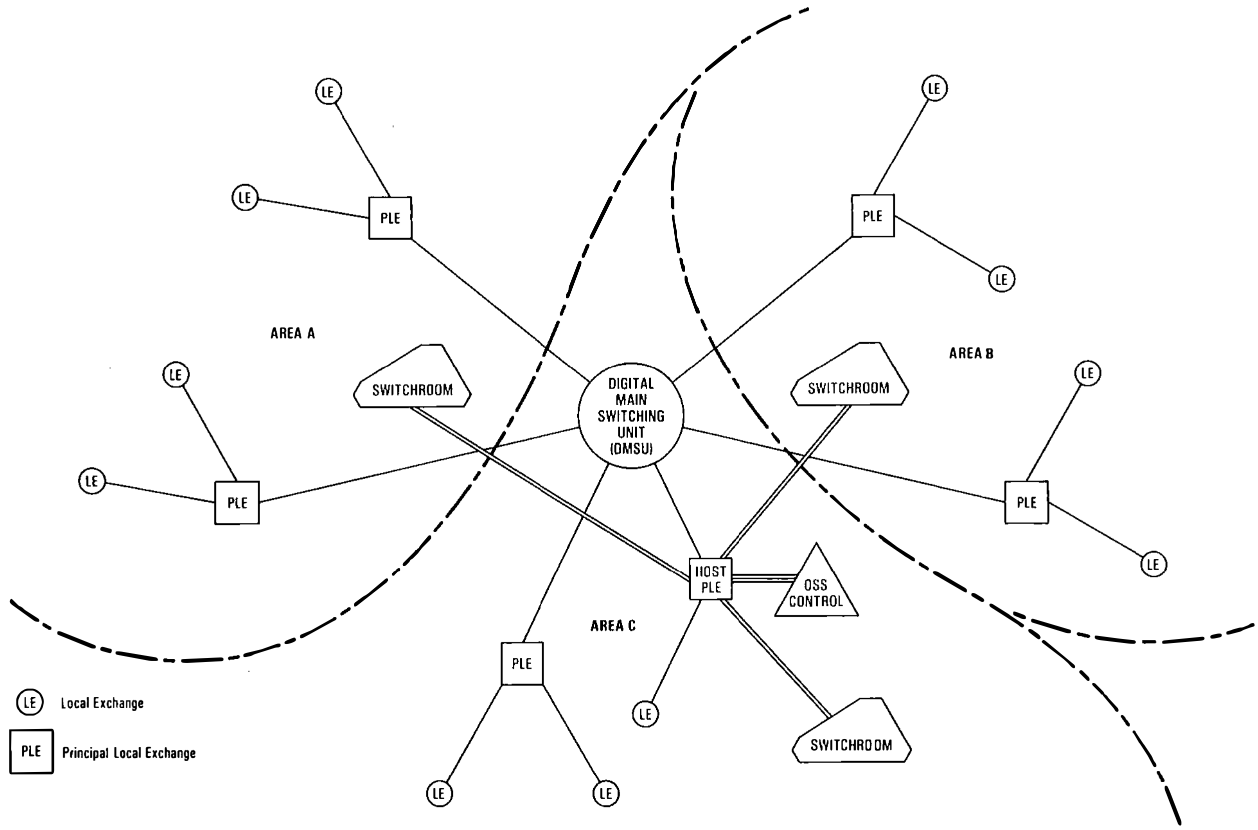
Fig. 1 shows an OSS hosted on a principal local exchange serving a catchment area extending over a large geographical area. The operator traffic is handled by 3 remotely-sited operator call handling centres. The call-queueing and distribution arrangements permit each centre to handle only the traffic originating in its local catchment area or otherwise as the administration requires. At night, all traffic can be concentrated to a single unit. Communication with the call handling centres is via standard 2048 kbit/s pulse-code modulation (PCM) systems, analogue circuits, or digital local lines as used for the integrated services digital network (ISDN). Where PCM systems are used, they can be switched via a digital distribution frame; this improves network security and allows a centre to be switched from one OSS to another if required.

The modular structure of the OSS ensures that changes necessary to meet the specific requirements of a particular administration can be met by a simple modification to the appropriate module. In addition to the subsystem facilities provided by a host exchange, the OSS requires 3 extra subsystems. These are: the operator call control subsystem (OCCS), which is responsible for call queueing, control, timing, accounting etc.; the operator conference bridge subsystem (OCBS), which provides the connection between the originating customer, the operator and the destination customer; and the operator interface subsystem (OIS), which includes the operator consoles and their associated controllers. Reliability, security and ease of repair have been prime considerations in the design of the OSS, and the use of standard subsystems minimises administration problems of spares holding and maintenance.

The 3 dedicated OSS subsystems can be easily integrated with another exchange without the need for extensive adaptations. Calls to the OSS are routed through the host exchange to a conference bridge, and the exchange simply treats the OSS as another node in the network. The connection from the conference bridge to the operator is under OCCS control and obviates the need to establish 2 paths to the operator should the call be extended to a distant customer. This is very important, especially where the operator may be a long distance away, since it optimises the use of the PCM links. To extend the caller to a distant customer, the OSS generates a new call from the conference bridge, via the host exchange, to the network. Control in the host exchange is simplified since it treats this as a new call and has no knowledge of the associated connection from the originating subscriber to the OSS. CCITT† No. 7 signalling

†Switching Development Department, British Telecom Major Systems

†CCITT—International Telegraph and Telephone Consultative Committee



PLE:Principal local exchange

FIG.1—Possible network plan for OSS showing management areas

is used for communication between the OSS and the host exchange and between the OCCS and the OIS.

OPERATOR CALL CONTROL SUBSYSTEM (OCCS)

The OCCS is principally a software subsystem, which uses a dedicated processor and hardware to interface with the host exchange. The software includes a small process in the host exchange. This process, known as *OPSIP*, facilitates switching and maintenance, and enables the OSS billing records to be handled by the exchange.

A block diagram of the OCCS hardware is shown in Fig. 2. It is based on the System X digital subscriber switching subsystem (DSSS) module controller and includes central processing utilities, a message transmission system (MTS) remote terminal unit (RTU) interface, CCITT V24/RS232 interfaces and an inter-processor link.

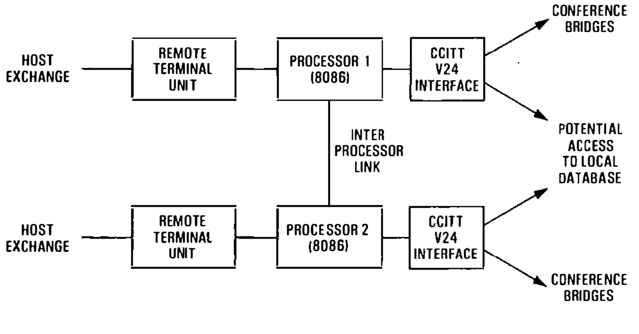


FIG.2—Block diagram of OSS hardware

The processor uses duplicated 8086 microprocessors, arranged to operate in worker/stand-by mode, and both programmable read-only memory (PROM) and random-access memory (RAM) can be provided. Throughput exceeds one million machine code instructions per second.

The RTU interface is a standard MTS unit, which supports CCITT No. 7 signalling and enables the OCCS to communicate with the OPSIP, with the operators' consoles via the OIS, or with the call processing subsystem in the host exchange.

Each processor is provided with sixteen V24/RS232 interface ports, whose most important use is for control of the OCBS conference bridges. Spare ports may be used to access a local database, printers etc.

The inter-processor link provides communication between the two processors. This supports a worker/hot stand-by equipment configuration in which the worker continually advises the stand-by processor of the current status of calls. Should a change-over occur, most of the calls are unaffected.

The OCCS software is the nucleus of the OSS. It includes the OPSIP, which resides in the host exchange processor. The OPSIP allows the OCCS to control the host exchange digital switching subsystem (DSS), to buffer the OSS billing records for transfer to the operations and maintenance centre (OMC) or to tape cartridge, and to communicate with the host exchange maintenance control subsystem (MCS). The MCS provides centralised control of the OSS resources, and aligns the OSS fault reporting, maintenance and system restoration facilities with those of the host exchange. The OPSIP also interfaces to the host exchange operating system to derive exchange clock time information for the OCCS and the OIS.

The OCCS software held in the OSS module controller consists of a number of separate programs. Examples are:

(*a*) the operating system,
(*b*) the input/output handler software, and
(*c*) the main applications software.

Great emphasis has been placed on producing a well-structured easily-understood and maintainable product. The design evolved by Plessey Telecommunication Research Ltd., of Poole, has used the following principles:

(*a*) The main applications software has been developed from high-level system-progression charts, which have been exposed to continual assessment and design review.

(*b*) PASCAL, a high-level self-commenting language, has been used in all but the most time-critical areas.

(*c*) The structure of the programs ensure that they are easy to follow. Functions have been modularised to make the maximum use of procedures and macros, and to avoid a monolithic structure. GOTOs have been avoided so that program flow is not interrupted. Variables and data structures are either:

(*i*) local to a procedure,
(*ii*) passed as a parameter to a procedure, or
(*iii*) global for the whole of the program. (The global data has a predefined meaning which is the same whichever procedure is entered.)

(*d*) Flow charts are kept up to date, are readily understood and are closely aligned to the source code. Great care is taken in the source code to refer back to the exact flow chart used. Procedures are broken down to small functional units and seldom exceed 50 lines of high-level language.

(*e*) The applications software and input/output handlers communicate via a strictly defined interface by sending data via reserved storage.

(*f*) The use of storage, linking of data structures and associated explanatory information is fully described in design documents.

Functions

The major tasks of the OCCS are:

Queueing

The OSS catchment area can be divided into a number of management groups, and incoming calls which cannot be handled immediately are queued until an operator is available to handle them. Separate queues are provided for each management group and each queue can cater for 16 levels of priority. Sophisticated call-diversion techniques are provided to cater for night concentration and other operational situations.

Call Distribution

Calls are distributed to operators on the basis of the management group, operator and console capability and, if appropriate, the length of time the operator has been waiting to accept a call.

Call Control

The progress of a call is determined by a sequence of events, which result from an input to the OCCS. The inputs may originate in the OIS (generally because the operator has keyed an instruction), from the network via the call processing subsystem in the host exchange, or from the OPSIP. The OCCS responds to these inputs in a variety of ways and generally undertakes many of the tasks commonly associated with the call processing subsystem in the host exchange. The OCCS also has exclusive control of the OCBS and may change the state of the conference bridge in response to messages from the OIS or from the call processing subsystem.

Call Charging

The OCCS validates data originating from the OIS and automatically times the calls. It also undertakes many of the tasks of the call accounting system in a System X local exchange to produce an itemised record for all chargeable operator calls. The record includes the price of the call based on the service, time of day, origin and destination of the call, call duration and supplementary facilities provided by the operator. For coinbox calls, the OCCS advises the operator of how much money to collect and generally speeds the connection of these calls.

Statistics

The OCCS generates a wide range of management statistics as an aid to efficient management of the system. These include details of time to answer, operator handling times, call queueing performance, and call diversion criteria. Traffic measurements on the OSS routes served by the host exchange are provided by the exchange.

OPERATOR CONFERENCE BRIDGE SUBSYSTEM (OCBS)

The prime function of the OCBS is to provide variable-state 3-port digital conference bridges. Each conference bridge mixes digital speech to enable 3 parties to converse together. The variable-state control allows the conference bridge to be configured in a number of ways and provides the following control modes for each port:

(*a*) cut-off; that is, input INHIBITED, output BLOCKED,
(*b*) monitor; that is, input INHIBITED, output ENABLED, and
(*c*) full communication; that is, input and output ENABLED.

Additional facilities enable ring tone to be input to any port and for the input to any port to be attenuated.

Every call via the OSS requires a conference bridge to enable the operator to converse with both parties, to split the speech path for conversation with one customer only, or simply to monitor the call. Two conference bridges may be switched via the DSS in the host exchange to provide an additional port; this is used typically to enable a supervisor to monitor a console, call or operator.

The OCBS hardware comprises a microprocessor-controlled control handler unit, which interfaces to the OCCS and is duplicated for security, and a speech processor unit (SPU). Each SPU interfaces to a single 2048 kbit/s 30-channel PCM link, and conference bridges are formed from a group of 3 consecutive channels. Hence, each SPU provides 10 conference bridges in all. The outgoing digital speech to each channel is the combination of the other two channels that form the conference bridge. When the operator is out-of-circuit, the conference bridge is effectively inoperative and digital speech passes unhindered from one customer to the other.

The OCBS is self routining and each conference bridge is periodically tested under the direction of the control handler unit. Faults are reported to the OCCS and, via the OPSIP, to the MCS in the host exchange for maintenance action.

A control handler unit can control 16 SPUs; thus a replication of the OCBS provides a total of 160 conference bridges. Power supply units are provided to ensure that loss of a single unit does not cause catastrophic failure of the OCBS. The handler units operate in worker/hot stand-by mode and a change-over will not affect the state of the conference bridges. The OCCS can control up to 6 replications of the OCBS, although in practice it is unlikely that so many bridges would be required. A typical provisioning level is 3 to 4 bridges per console.

OPERATOR INTERFACE SUBSYSTEM (OIS)

The OIS includes the operators' consoles, which are referred to as *console work stations* (CWSs) and their associated common equipment, known as *operator distributor units* (ODUs). Each replication of the ODU can serve up to 30 consoles, and the preferred interface to the host exchange is via a 2048 kbit/s 30-channel PCM system which may be duplicated for security. Maintenance and diagnostic control of the OIS resources uses the OPSIP and the host exchange facilities previously described.

Console Work Station

The CWS comprises a commercial visual display terminal and keyboard (VDT), and associated operator's telephone circuit. It has been the subject of considerable ergonomic and human factor study, under the auspices of the BT Human Factors Advisory Service provided by the British Telecom Research Laboratories. Their advice has been sought on the choice of VDT, work-station furniture, telephone headset, the operators' immediate working environment (for example, lighting, heating, acoustics, decor, layout etc.), man–machine language and form of dialogue between the operator and the system, personnel factors and training. Many of their recommendations have been included in the design, but the process is one of continuous evaluation.

The VDT, keyboard and headset are the means by which the operator provides, controls, monitors and records the service given to the customer. Factors determining the choice of VDT and keyboard are:

(*a*) they must meet the requirements of a universal console for all operator services including connect, enquiry and directory assistance calls and be suitable for use by operators, trainees and supervisors alike;

(*b*) they must be readily available as a standard product;

(*c*) they must satisfy the most important human factor considerations; and

(*d*) they must be capable of enhancement to suit specific user needs, and facilitate system evolution.

The design allows for the use of a range of modern lightweight headsets as an administration option. Call information is formatted and displayed to the operator in a manner appropriate to the type of call the operator is handling at the time. The display also includes fields for the display of call supervisory information allowing the operator to retain control of up to 3 calls at a time. The design automates many of the tedious and time-consuming tasks undertaken by telephone switchboard operators, eliminates the need for the telephone toll ticket, improves operator efficiency and enables a better service to be given to the customer.

Where necessary for service bureau applications, a simple key-and-lamp unit can be used in lieu of a VDT.

Operator Distribution Unit

A block diagram of the ODU is shown in Fig. 3. For simplicity, the speech paths have been omitted. Communication between the ODU and the host exchange is via 30-channel PCM links, with time-slot 16 allocated to data. The link is duplicated for security but, in the case of a fault, the speech and data for up to 30 operators can be handled on a single link. The ODU consists principally of 2 functional parts: the operator message handler (OMH) and its associated MTS RTU, and the console interfaces. The former are duplicated for security and the latter are replicated on the basis of one unit per 3 consoles.

The OMH provides the interface to the PCM link and is responsible for message handling and the generation of timing and address information for coding and decoding the operator's speech. For convenience, the OMH interfaces time-slot 16 to the MTS RTU, which is responsible for data communication with the host exchange and the OCCS. The RTU caters for messages for individual consoles, groups of consoles, or for internal ODU applications. The RTU provides a high degree of error protection, further enhanced by the OSS protocols which invariably validate and acknowledge the messages.

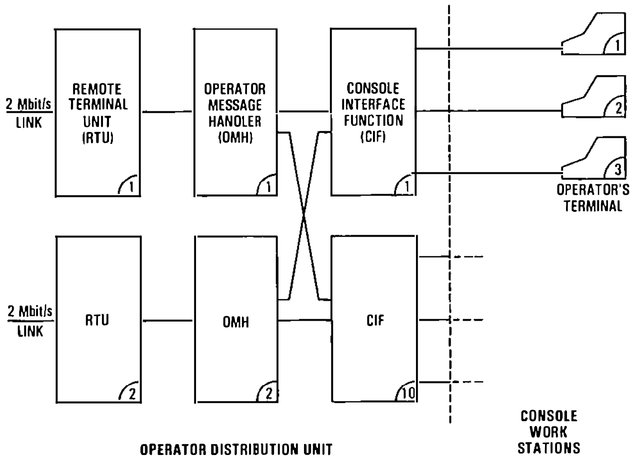


FIG.3—Block diagram of operator interface subsystem

The console interface provides access to the operator consoles and includes data handling software for 3 consoles per unit. The hardware includes an 8086 microprocessor, with both PROM and RAM. It also includes the operator's telephone circuit and provides for analogue-to-digital conversion of the operator's speech. The console interface unit is linked to each OMH and is aware of the in-service state of the OMH. If a PCM link or an OMH fails, the console interface selects the other OMH and corresponding link to provide an uninterrupted service. The software for the console interface has been developed on similar lines to the OCCS software. It is responsible for data and message validation, display and keyboard control and provides backing store for display data, thereby reducing the number of transfers to and from the OCCS.

OSS INTERWORKING AND COMMUNICATION CONSIDERATIONS

CCITT No. 7 Signalling

The OSS makes extensive use of the System X message transmission subsystem, which implements the message transfer part of CCITT No. 7 signalling. Each ODU, OCCS module controller and, of course, the host exchange has a unique address (known as a *point code*) which is used for directing messages to their destination. The OPSIP is a dedicated user of the MTS and uses the same point code as the host exchange. The host exchange acts as a signal transfer point for messages passing between the OIS and the OCCS.

Call Handling—System X Traffic

Traffic routed via the OSS and the System X network uses CCITT No. 7 signalling throughout, and fully exploits the capability of stored-program control and common-channel signalling. This enables the OSS to display automatically the originating and destination customer information, and supports new message-based facilities; for example, operator priority access, and enhanced operator-to-operator calls. Undoubtedly, the automatic display of this information has a significant impact on operator performance.

Call Handling—Non-System X Traffic

The OSS has been designed to handle traffic from all types of exchange. This is achieved by using the System X signalling interworking subsystem (SIS), which supports a comprehensive range of signalling systems. These can interface directly to a System X exchange or may be connected digitally via remote 30-channel PCM signalling systems. To compensate for the limited information available from non-System X exchanges, the OSS interprets the interworking-circuit identity to provide the calling information for display to the operator. Such information can include the management group, originating exchange code, call class and, in some circumstances, the telephone number of the calling line.

Interworking With Data Networks

For BT applications, the OSS is being enhanced to interwork with a proprietary directory assistance system and to provide 'front office' capabilities. The latter will enable an operator to interrogate and retrieve data from a variety of Telephone Area support computers and databases; typical use will be dealing with customer sales, account and provision of service enquiries. Standard CCITT Recommendation X25 interfaces and signalling protocols will be used by these databases, which may be accessed from the OSS via the host exchange. Communication with the host exchange from the OSS will be via the MTS and the exchange will provide the interworking from the MTS to the X25 interfaces. These facilities will provide the means by which the service can expand to meet the needs of the customers and administration alike.

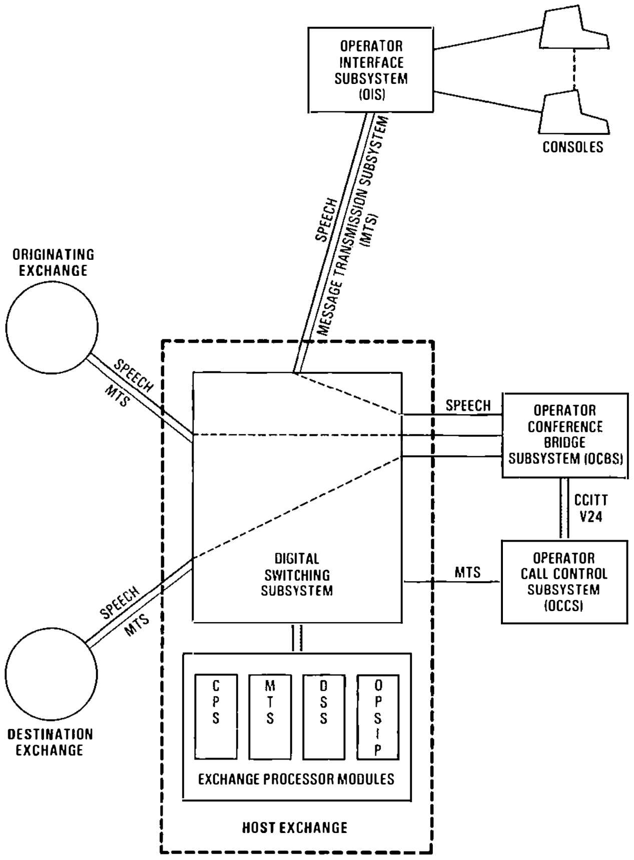


FIG.4—Block diagram of OSS and the host exchange

OUTLINE OF A TYPICAL CALL

The OSS caters for directory assistance, enquiry and connect service calls. As an example of a BT connect service call, consider that a disabled customer requires to be connected to a Freefone customer. Operators log-on by inserting their headset plug and keying their identity code. This is acknowledged by the OCCS, which replies with a message to the OIS and results in a display confirming the operator's authority. The operator is then able to accept a call by pressing a READY key. Fig. 4 shows a simplified block diagram of the OSS and the host exchange.

When the local exchange detects the OFF HOOK condition on a disabled customer's line, it generates a fixed-destination call to the OSS. The call is connected to a free conference bridge by the call processing subsystem in the host exchange and a message is forwarded to the OCCS. The OCCS interrogates the exchange to determine the call class (disabled customer) and the identity of the calling line. The OCCS examines the status of the queues and, if a queue place is available, queues the call and instructs the OCBS to return ring tone to the caller.

When an operator presses the READY key, the OIS sends a message to the OCCS. On receipt of this message, the OCCS allocates the call, returns an *operator answer* signal to the local exchange, instructs the OCBS to remove ring tone and sends the calling line information to the OIS for display to the operator. The OCCS also sends a message to the OPSIP, which instructs the DSS to set up a speech path from the conference bridge to the operator. A conversation path is therefore provided between the operator and the caller via the conference bridge.

In the example chosen, the caller requests a Freefone call and quotes either the name of the Freefone customer (Alpha Freefone service), or the Freefone number. This information is keyed in by the operator, who then operates a SET UP DESTINATION key. The instruction, together with the Freefone data, is sent from the OIS to the OCCS via the MTS. The OCCS automatically translates the Freefone information into a telephone number and generates a new call via the host exchange using this number. The call processing subsystem in the host exchange sets up the call from the conference bridge into the network. Network responses are returned to the OCCS and a suitable display is given to the operator. When the operator is certain the call has been connected satisfactorily, the call is relinquished from the operator's console. This releases the speech path from the conference bridge to the operator and clears the call details from the console display. The operator is then free to handle a new call. The disabled customer's call continues automatically under OCCS control. When the customers clear, call timing ceases and the OCCS releases the connection by sending release messages to the network, prices the call and forwards a billing record to the OPSIP for onward transfer to the billing centre. The billing record, in this case, identifies the Freefone customer as the paying customer. During the course of the call, a range of statistics is updated as an aid to efficient management of the system.

OPERATOR AND MANAGEMENT FEATURES AND FACILITIES

The use of a user-friendly universal console, which eliminates many of the tedious and time-consuming tasks of normal switchboards, greatly enhances the switchboard operator's job. Important opportunities will arise for introducing new services and facilities. The operator is freed from reliance on paper records and can concentrate on the quality of service provided to customers. This is especially so if modern technology is used to provide access to external databases in pursuance of the front-office concept.

The efficient use of the OSS call queueing and distribution facilities greatly improves the local manager's ability to staff the system effectively and may even create the opportunity to introduce more flexible working arrangements. Certainly, call-diversion and night-concentration facilities ensure that an optimum service can be provided at all times.

Use of standard office accommodation for the console work stations significantly improves the operators working environment. Separation of the OIS from the OCCS enables switchrooms to be sited in the most appropriate areas and this, in turn, eases the twin problems of recruitment and travelling, to the benefit of all.

ENHANCEMENTS FOR BT USE

The OSS has been developed to provide a basic system, fully capable of enhancement to meet the needs of any telephone administration. The system is currently being enhanced to provide a number of additional facilities for the BT inland service.

Many of the BT enhancements refer to the retrieval of information from a variety of sources. The major enhancement is to interwork fully the OSS with a proprietary directory assistance system. This permits the operator to handle directory enquiry and connect traffic on the same console. The OSS operator should even be able to handle the enquiry and, subsequently, extend the call without the need to re-key the call information.

Other enhancements include:

(*a*) translation of exchange names to all digit numbers;
(*b*) validation of credit card numbers;
(*c*) translation of Freefone numbers to telephone numbers;
(*d*) provision of local dialling lists;
(*e*) derivation of caller information from path of entry data for traffic from non-System X exchanges;
(*f*) provision of a completed-call file to permit billing records to be examined locally; and
(*g*) provision of a suspended-call file for delay, booked, fixed time and reminder calls.

The provision of these facilities, coupled with development in support of the front-office proposals, will ensure that the System X OSS can meet the changing needs of today and the challenge of the future.

CONCLUSION

This article has described the System X OSS and its associated subsystems. It has shown that technology, far from eliminating the role of the telephone operator, may be used to improve the service and enable new services to be introduced for the benefit of all. Enhancements for the OSS are in hand to extend the basic system to provide additional services for the BT inland service, with special emphasis placed on data retreival from external databases. It is expected that the OSS design will allow the system to evolve and meet future requirements however demanding they may be.

ACKNOWLEDGEMENTS

Thanks are due to all the engineers, both in BT and the Plessey Company plc, who have contributed to the development of the OSS, and to the author's colleagues in BT who provided assistance in the preparation of this article.

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The International Leased Telegraph Message Switching Service

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UDC 621.394

This article describes some of the facilties offered by message-switching services in general, the international leased telegraph message switching service and some of the equipment it uses. The article also provides a simplified overview of the operation of the latest equipment in use in the service.

INTRODUCTION

The international leased telegraph message switching (ILTMS) service in the UK has been developed over the past 12 years to provide a comprehensive service to both large and small businesses.

ILTMS is a service dedicated to users of international private leased circuit networks. Access to the system is available via private circuits, the public switched Telex network and message switching centres operated by other administrations.

MESSAGE SWITCHING

Message switching is a means of passing information across a communications network by using a whole message as a unit for transmission. A message, for the purpose of message switching, consists of a start-of-message sequence, a serial number, an address, the text of the message and an end-of-message sequence. The text may be of any length; typically, the whole message must be less than 3000 characters. An example of a message is shown in Fig. 1.

Message switching was introduced into the telegraph network to overcome the need of having one circuit connecting each destination that an office may use. Initially, this was done manually via central offices, messages being sent to the central office and stored on paper tape until they could be forwarded to their destination; this technique was known as *torn tape*. From the late-1960s, electromechanical and, later, computer technology was used; computer technology, in particular, is ideally suited for message switching applications.

Most of the features of the manual systems are retained in modern automatic switches, partly for historical reasons, but mainly because they offer distinct advantages. The main features are

(*a*) circuit serial numbering,
(*b*) store-and-forward working, and
(*c*) priority working.

†International Business Services, British Telecom International

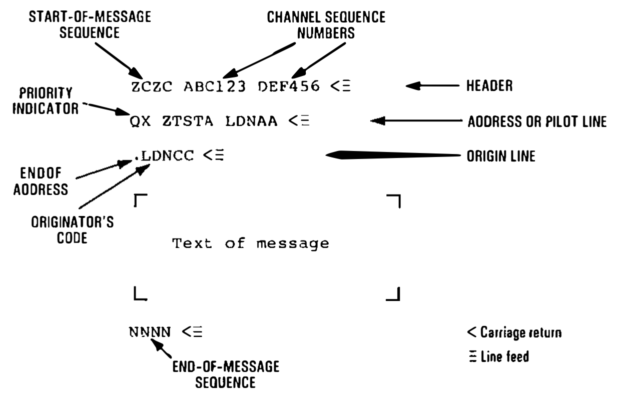


FIG. 1—A typical message format

Circuit Serial Numbering

Serial numbers are added to each message on transmission. The retention of a ledger at each switching node, relating the serial number used to transmit each message to the number under which it was received, allows messages lost because of circuit failures to be traced back to the originator for retransmission. Each serial number consists of a 3-letter prefix identifying the circuit and a 3- or 4-digit number.

Store-and-Forward Working

With store-and-forward working, a complete message must be received at the switching node before any attempt is made to pass the message on to the destination. This allows a message to be accepted for transmission even though the terminal at the destination may not be able to receive it at that time, perhaps because it is already sending another message or because it is faulty. The practice of allowing queues to mount up for outgoing routes smooths traffic peaks (say, at the start and end of a day's trading) without the need to provide additional circuit capacity that would be idle for much of the day.

Initially, networks worked at a line transmission speed of 50 baud; but with developing teleprinter technologies the store-and-forward method of working allowed for the addition of circuits of varying speeds, since there was no connection between the terminal points in an information exchange. Similarly, it was a straightforward step to add multiple-code working, provided of course that switching nodes in the network could handle the new codes. The normal code used on the early networks was the International Telegraph Alphabet No. 2 (ITA2) (a shifted 5-bit code used in the Telex network). It was therefore necessary to reprogram or replace switching nodes to enable the 7-bit code International Alphabet No. 5 (IA5) to be introduced.

Priority Working

Store-and-forward working has one large disadvantage: the introduction of long cross-network delays. To transmit a message across a network with just one switching node, it must first be received by the node and then passed on to its destination. So, for a 1000-character message, the minimum time from the start of transmission until the completion of reception in a single node network is

$$2 \times 1000 \times \frac{7 \cdot 5}{50} = 300 \text{ s},$$

assuming 50 baud transmission.

In a multi-node nework, 150 s must be added for each additional node that the message must traverse, plus any time taken to clear messages which may have formed a queue for a route the message must pass. Although the problem of long transmission times is eased by the use of faster transmission speeds, queue delays on busy routes can still be long, particularly for networks which have large peaks of traffic load during the day and carry a few messages of an urgent nature. Multiple circuit routes are not a solution, as a costly resource may be idle for much of the day to accommodate a high peak for an hour in the afternoon.

A partial solution is to provide a priority structure, whereby important messages arriving for output are transmitted before the more ordinary messages, which may have been in the queue for some time. Priority structures vary between a simple 2-level arrangement and a scheme of up to 6 priority levels in which the highest is reserved for messages of a life-or-death nature.

Special facilities

Modern message switches provide a number of additional features, which include

(*a*) conferencing,
(*b*) multiple-address delivery,
(*c*) message retrieval, and
(*d*) network interfacing.

Conferencing

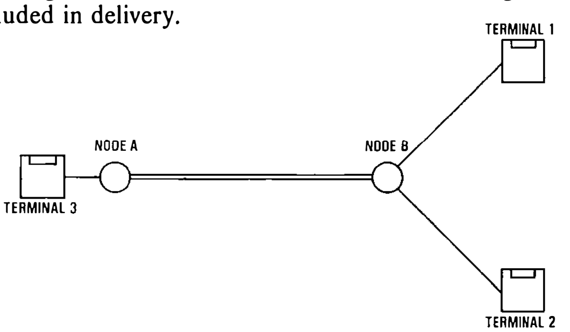
If a conference is established between a number of circuits, each character received by the switch from one of those circuits is transmitted to all of the circuits in the conference. In some early implementations, it was necessary for all of the circuits to run at the same speed and in the same code; however, today speed and code are immaterial, thus allowing a data link to be established between two terminals of differing speeds and codes using the switching node as a converter. No other traffic can be received during a conference and it is usually necessary for all circuits involved to be on the same node.

Multiple-Address Delivery

As the message in Fig. 1 shows, the address consists of a number of groups of characters. Each character group or address indicator is an address in its own right. Each address indicator, when analysed against tables stored in the switching node, may result in delivery to many destinations. This facility enables automatic delivery in accordance with a stored distribution list, or a combination of several of these lists. Although a given destination may appear more than once in an address, only one copy is sent. To avoid messages breeding in a multi-node network (Fig. 2), 2 different techniques are used:

(*a*) address stripping, and
(*b*) address responsibility checking.

Address stripping requires that, before a node transmits a message to a route, all address indicators are removed, except those that caused delivery to that route. Thus, addresses which may cause the second node to send the message back are removed. Address responsibility checking requires that a node can distinguish, according to the point from which the message was received, the routes to which a message must be sent; this allows the route of origin to be excluded in delivery.



Note: A message sent from terminal 1 and including both terminals 2 and 3 in the address will be passed to node A, which will also decode the address and pass one copy back to node B and so forth unless measures are taken to prevent it.

FIG. 2—Message breeding

Message Retrieval

Message retrieval was first provided as an aid to network security. In the event of a loss of a message in a network, with retrieval it is necessary to refer only to the last node from which the message was transmitted, obviating the need to ask the originator. Thus, line breaks between nodes can be dealt with simply by having the missing sequence numbers retransmitted from each node's retrieval store.

In the early systems, retrieval from up to 3 days only was provided, as this gave all the security required. Newer systems offer one month and more, in some cases, enhancing the basic retrieval by serial number capability with search on word key and subject features, some of which are highly sophisticated. In addition, mailbox facilities have been added to some systems.

Network Interfacing

Traditional message switching networks consisted of a number of telegraph terminals connected by dedicated circuits to one or more switching nodes. Networks have, for many years, had interfaces to the Telex network. This is an easy step, as the line speed and codes are similar to those already used in message switching, although the complications of Telex line signalling and the exchange of *answer-back* codes are great. Today, message switching is using interfaces to the packet-switched network and even providing dial-up access for occasional users.

Comparison with other Network Types

There are 3 types of basic switched network: circuit switching, packet switching, and message switching. Table 1 summarises the main features of these networks.

DEVELOPMENT OF THE ILTMS SERVICE

Over a period of many years, British Telecom (BT), then part of the British Post Office, provided an international point-to-point telegraph service. Much use was made of radio circuits, and channel space was costly; so circuits were principally part rate. Despite a number of requests, it was felt that to provide message switching on an international basis would be too costly and would not justify the investment. In 1968, as a result of this decision, several large international customers moved their communications centres

TABLE 1
Summary of Network Features

Feature	Network Type		
	Circuit Switched	Packet Switched	Message Switched
Allows data to be sent without a call set-up procedure		Note 1	✓
Allows data to be sent to fully occupied destinations			✓
Fixed resource allocation	✓		
Allows communication between terminals of differing codes			✓
Allows communication between terminals of differing speeds		✓	✓
Conversational communication	✓	✓	
Allows urgent messages through more rapidly when congested			✓
Multiple message delivery			✓

Note 1: possible if a datagram facility is available

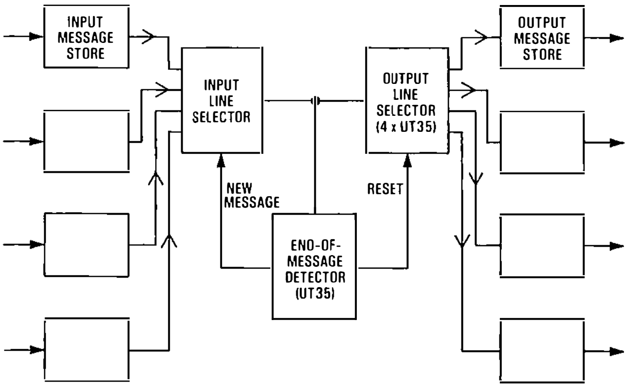


FIG. 3—Block diagram of a 4-channel electromechanical message switch (happy box)

away from the UK to the continent where such a service was available.

In order to stop the loss of customers, a 4-line electromechanical switch (see Fig. 3) was brought into use by what was then the International and Maritime Telecommunications Region of BT. This switch consisted of a line sequencing unit to poll the incoming circuits, a number of character recognition units (UT35), and a tape store for each output circuit. Input storage was provided by auto transmitters (Auto 2F). Such an arrangement is almost a circuit switch, requiring all circuits to be at the same speed. The introduction later of tape stores on the input circuits allowed circuits of different speeds to be operated and the speed across the switch to be higher than the line speeds. This arrangement, known as a *happy-box*, provided a basic service, and was sufficiently sophisticated to allow for the irregular character transfers on radio circuits, to incorporate the part-rate circuits in use at the time and to give priority to the primary circuit.

Four lines served to keep the customers happy, but a better service was needed, one which only a proper message switch could provide. Insufficient funds were available for any extensive work, but fortunately the decline of the radio service meant that a number of processor-controlled D110 storage units became available for other uses. In collaboration with their manufacturer (Hasler GB), these units were modified to form the M110 message switch. A pilot service offering a 16-line switch with multiple address and priority capabilities opened on these units in 1971.

The service provided by the M110 message switch proved fairly popular and funds were made available for its development. Inevitably, as the capability of the service grew, the expectation of customers grew ahead of it and the 16-line M110 was found to be too small for some large customers. In 1973, an order was placed with the same manufacturer for a 64-line message switch, known as the *M150*, which was to provide retrieval, Telex interworking, the possibility of dividing the switch into more than one unit and many other features.

The necessary hardware for the M150 was provided by the Swiss parent company of the UK supplier from components of a Telex switch that it already manufactured. The software was seen to be a much larger task and was split into 5 phases, some of which were themselves introduced in parts. Phase 1 proved unsuitable and was never used, so service opened in 1975 on phase 2A. In addition to the basic message switching facilities, phase 2A offered retrieval and a simple statistical package.

Phase 2B heralded the advent of the broadcast facility (the same message sent to several channels simultaneously), and conference working with a maximum line speed of 200 baud. The automtic generation of *line-check* messages every 30 minutes improved the detection of circuit failures. At about this time, a need for a still larger switch was recognised and several 128-line systems were ordered, with necessary software to be provided under phase 4.

Phase 3 was to provide a Telex interface; phase 3A was felt to be inadequate and so phase 3B entered service in August 1977.

Partly because of the change to 128-line working and partly because of the introduction of code conversion to accommodate IA5, phase 4 took some time to implement. Some of the large capacity systems had been equipped with a different disc drive and interface, so that 3 versions were now needed. The first of those systems with the newer removable-pack disc drives was brought into service in December 1979, the 128-line version for the machines with the normal disc drive in March 1980 and the 64-line version in June 1980.

Although phase 5 was accepted from the manufacturer, it was never put into service in its complete form. Some parts have been extracted and incorporated in phase 4 by British Telecom International.

During the development of phase 4, another more advanced message switch was ordered. A contract was placed with Ferranti Ltd., which subcontracted the software to Logica Ltd. for a 128-line message switch with facilities largely similar to that offered by the final M150, but with the addition of automatic recovery in the event of failure and with the capacity for a medium-speed inter-switch link. Development started on this system in 1979, and it went into service in May 1981.

CURRENT ILTMS SERVICE

The Hasler M110 (which has had a microprocessor-based Telex interface added to it) and the M150, together with the Ferranti Argus 700Es, provide the current ILTMS service.

The essential features of the equipment configuration are shown in Fig. 4. Service is provided on an unsecured basis; one machine being kept available for use as a reserve. Telegraph channels are patchable between machines in blocks of 32 to facilitate a rapid change-over in the event of a hardware failure. A flexibility point is also provided in each medium-speed channel, on an individual basis, as only 4 such channels can be connected to each processor. A further flexibility point in the connection from each machine to its disc drive allows the customer's disc with all of the information necessary for recovery to be moved as well.

Disc patching was first introduced for the older Hasler M150 systems, which were fitted with fixed-head discs in which the media could not be exchanged. Later types of equipment have been fitted with moving-head drives with removable packs; however, in a failure situation, it is not desirable to move disc packs, as a damaged pack may be removed from a faulty drive propagating the fault to another drive. Exchanging interface cables avoids this possibility.

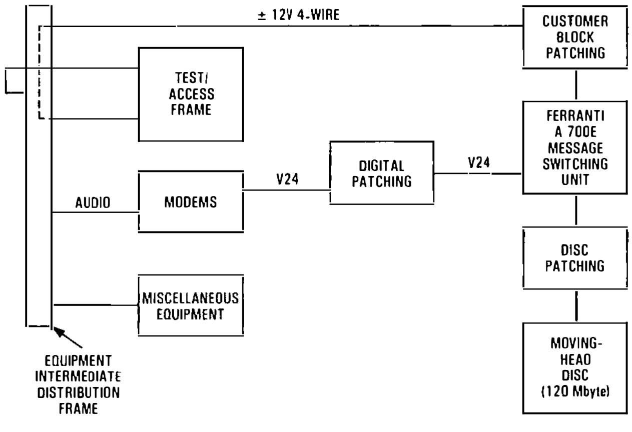


FIG. 4—Configuration of ILTMS equipment (Ferranti)

Once the customers' connections have been moved, the latest generation equipment recovers all traffic itself automatically. Earlier types of equipment have to go through the manual process of having disc pointers checked and re-established, which takes some time. Twenty-four hour maintenance coverage is provided so that down times on customer networks are short.

A large network may consist of from one to three switching nodes. Each node supports up to 100 teleprinters with network control facilities, high-speed trunk circuits and interfaces to the local Telex network at each node. Such a network will carry much of the trade of a large banking or trading company. The nodes are located at points which are advantageous to the company either near a major trading centre, or at the point at which communications costs are competitive and services best. Many companies favour London for their European node, other nodes being typically in Tokyo and New York. Small networks are more normal, some having a single node and only 8 or 10 terminals. Large networks, such as that described above, are supported by only the largest of companies.

PRINCIPLES OF OPERATION OF THE LATEST EQUIPMENT

Hardware

The latest generation of equipment is based on a Ferranti Argus 700E processor with 256 Kword (16 bit words) of ferrite-core memory, of which 64 Kword is available for program and the remainder for tables and messages. The system has a 120 Mbyte moving-head disc drive, a medium-speed line multiplexer and 2 telegraph line multiplexers. Control facilities include an engineering console, a paper-tape reader and punch, a line printer operating at 400 lines per minute, and a communications isolation card for extending system alarms to the station alarm display and isolating the telegraph channels in the event of a system failure.

The system is bus structured with the central processor unit (CPU) connected to its memory and the system peripherals by means of the store bus, which requires a bus extender to accommodate the top 192 Kword of memory and the 3 multiplexers. A lower-capacity peripheral bus gives access to the control peripherals. The peripheral units on the store bus have direct memory access facilities and are referred to as channels; those on the peripheral bus transfer characters to the CPU under program control. (See Fig. 5.)

Characters are transferred to and from the telegraph and medium-speed channels through multiplexers. The telegraph mutlipexers scan the connected channels according to a preset routine. Received characters are placed in the system memory, which is divided into pages of sixteen words.The multiplexers perform code conversion, Telex dialling and *answer-back* checking, message transmission, character reception and detection of certain significant character sequences such as the *start-* and *end-of-message*. In addition, line lengths in messages are checked to prevent overprinting and character repetition in case an auto transmitter has jammed.

The operation of the multiplexer is controlled by varying the line control terms in the multiplexer's control store, which is sited in the main processor's memory-address area. These line control terms govern the events for which the multiplexer searches in the character sequences transmitted, and the results which the multiplexer returns.

A multiplexer uses a channel interrupt message (CIM) to communicate significant events to the main processor. Most of these messages do not cause a direct CPU interrupt; they are merely placed in a buffer. Some, however, do interrupt the processor directly; for example, *CIM buffer full* and *no free pages*. Each of these conditions is urgent as they would cause events or characters to be missed if they were left unattended.

The operation of the medium-speed multiplexer is similar, and the disc controller also uses CIMs to communicate with the processor. Hardware interrupts and, more important, channel control signals such as *reset* are communicated via the channel control highway.

System Software

The entire system software consists of the message-switching software and a number of off-line processes that perform tasks such as assembly of system tables, loading of software and tables to disc, and analysis of information in dumps of failure situations. The following description is confined to the message-switching software. Only that part of the software handling messages passing to and from the telegraph multiplexer is presented. Messages destined for the medium-speed multiplexer are similarly handled by all subsystems except line control.

The message-switching software can be conveniently split into input processing, output processing and retrieval; a number of modules and data structures are involved in each.

Input Processing

Characters are received from line by the multiplexers and placed in system pages. Each page contains 16 words and so holds 30 characters, the first word being used as a chain pointer. Significant events such as start-of-message and end-of-message are signalled to the software by using CIMs. The multiplexer places the CIMs in a primary CIM buffer, from where they are copied to a larger secondary CIM buffer by a high-priority process in the line control module. The task-mode part of low-speed line control, which is activated at intervals and scans the CIM buffer, takes the necessary action on each CIM as it is found. (See Fig. 6.)

Messages in the course of reception are described by an input message status block. This structure informs the system of where (in which page) the message starts, of its length and the stage of reception it has reached. Once a message is complete, its input message status block is placed

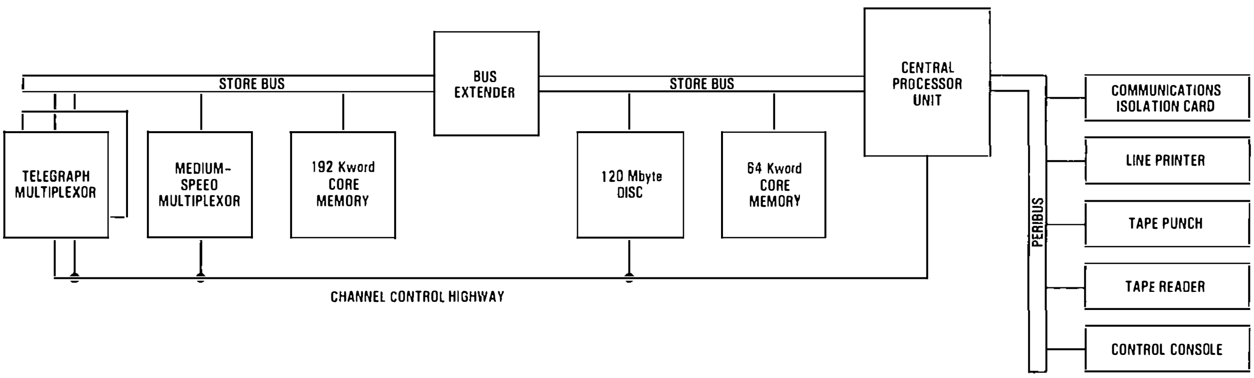


FIG. 5—Block diagram of Ferranti Argos 700E ILTMS switch

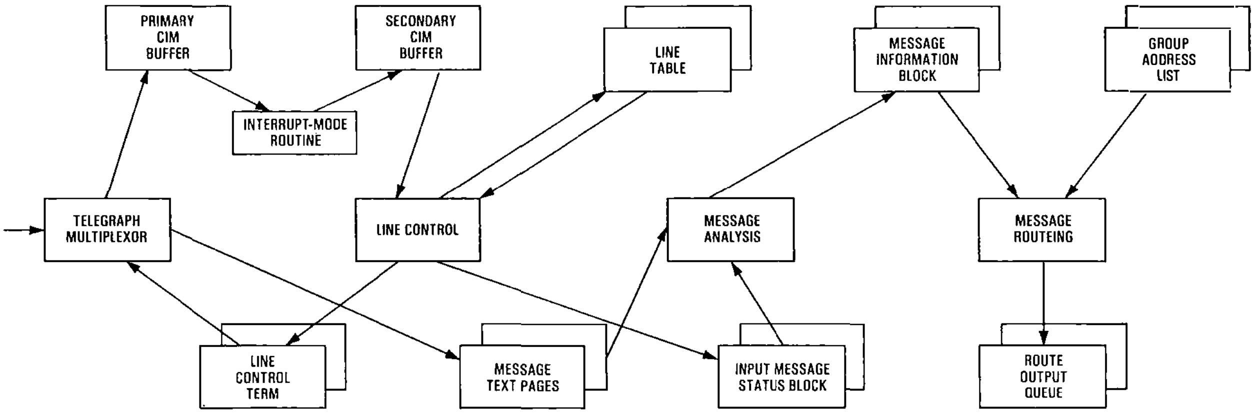


FIG. 6—Information flow in input processing

on the input ready queue for the line on which it was received. The message is now ready for processing.

The module that performs the initial processing is called *message analysis*. This module seeks to isolate all the features of the message that may be needed by other modules, and thus avoids scanning a message for such features as input serial numbers and address indicators more than once. During this process, message analysis makes up a message information block, which is used to store the information it extracts. Once complete, the message information block is tacked on to the front of the message, where it remains while the message is in the system. Message analysis also makes up a message information table which forms a reference point for the message, allowing the larger message information block and the message itself to be written to disc and the main-memory copies to be deleted. The message information table is placed in a queue for the disc handler to scan and write the message to disc for retrieval purposes.

Once its processing is finished and the message information block is complete, message analysis makes a call to message routeing to direct the messages to output routes. The address indicators, already identified by message analysis, are taken from the message information block and compared with a stored list of address indicators. On finding a match, the routeing list entries for that address are extracted. These, together with associated responsibility tables, specify the output routes to which messages with that address indicator must be sent. Message routeing makes up a route output queue entry for each route and places it in the route output queue for that message; it makes appropriate allowance for the message priority. The route output queue entry forms a pointer indicating the position of the message information table and, hence, the message for the output processing routines. This entry remains in place until it is time for the message to be output from the system.

Some messages will be found to be inadequate by either message analysis or message routeing. These messages are passed to the service message generation module, which forms an appropriate service message and places the message in its route output queue. Messages that form commands are placed in internal queues for the command analysis module.

Output Processing

The work involved in preparing and causing a message to be output is co-ordinated by output administration. This module also handles the work involved when certain network control commands which affect the routeing of a message are required. Output administration scans the output routes making a call to output line selection for each route.

Output line selection examines the circuits in the route and the messages waiting to be output, and matches circuits with messages. If no circuit is available or no message is suitable, no action is taken; otherwise, the route output queue entry for the message is marked EXTRACTED. Queue entries are not deleted until the message is completely transmitted. (See Fig. 7.)

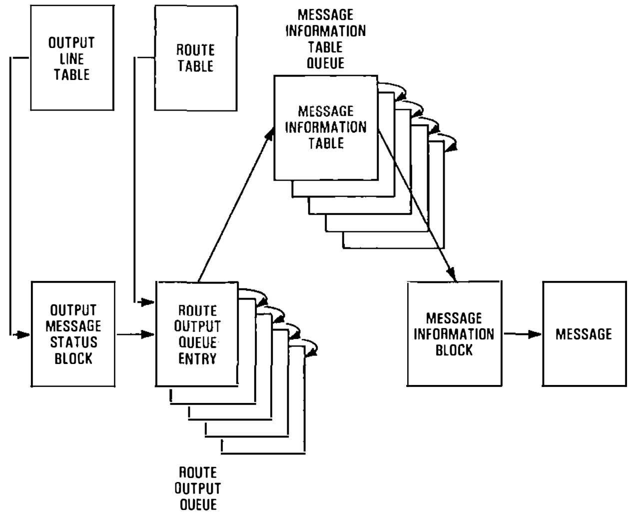


FIG. 7—Relationship of message transmission structures

Once a message is selected, output administration creates an output message status block and places it in the selected queue for the circuit concerned; one such queue exists for each circuit in the system. A call is then made to output message tailoring to create new heading and address lines for the message to be output from the information in the message information block; this section is then linked to the existing message text.

Line control is informed that the message is ready for output by a pointer to the output message status block being placed in the next output location. With few exceptions, it is only necessary for line control to pass a pointer (to the head of the chain of pages which forms the message) to the telegraph multiplexer for the message to be output autonomously by the multiplexer. Once transmission is complete, the multiplexer informs line control by means of a CIM and the output message status block is placed in the ledger queue.

The ledger module does 2 things: it makes up ledger messages for transmission at the appointed times; and from the output message status block, it produces a ledger entry and generates a transmission record for the message. The transmission record is placed in the group transmission record queue and the output message status block is released for reuse by the output administration module.

Retrieval

Retrieval in this system is supported by the recording of messages on a magnetic disc. Once the message is in the

TABLE 2
Operating Performance of ILTMS Systems

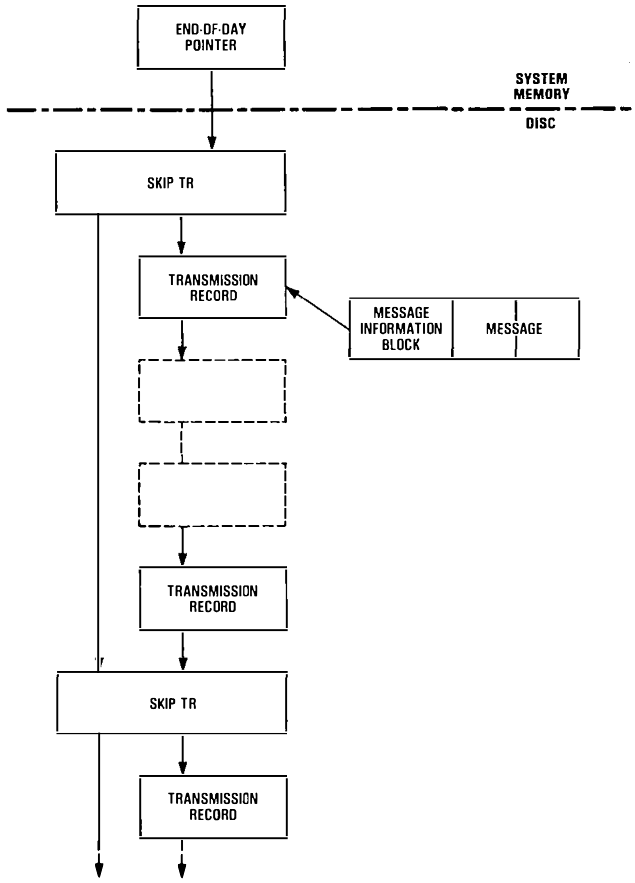
Equipment	Network Percentage Availability		MTBF (hours)		MTTR (minutes)	
	1981/82	1982/83*	1981/82	1982/83*	1981/82	1982/83*
Hasler M110	99·97	99·97	790	1235	13·6	21·1
Hasler M150	99·90	99·93	418	683	23·7	28·7
Ferranti A700E	99·98	99·98	880	1068	8·1	11·7

*April to January only
MTBF: mean time between faults
MTTR: mean time to recover
Note: figures include hardware and software failures.

system and a message information block and a message information table have been completed, the message information table is placed in a queue which is scanned by the disc handler. The disc handler then copies the message information block and the message contiguously to disc. Once this has been done and message routeing is complete, the main-store copy of the message may be deleted; this leaves only the message information table, which contains the disc address of the message, as a reference to the message. This process of 'offloading' causes a slight complication in output processing as it is necessary to ensure that a copy of the message to be output is in main store.

Transmission records are also written to disc, this being the purpose of the group transmission record queue. These records form the retrieval key for the message. Transmission records for each output circuit are chained together on disc to provide a thread that can be followed when a message is being sought. To speed up this searching process, a retrieval end-of-day pointer is kept so that only one day's traffic needs to be searched. In addition, a backward reference is written, in the form of a *Skip TR*, every 30 transmission records. The Skip TR points back to the previous Skip TR and allows the chain to be followed very quickly as not all transmission records need be examined. (See Fig. 8.)

When a request is received for the retrieval of a message, the end-of-day pointer for the required day is located first. Then, the chain of Skip TRs is followed until the correct range is found; finally, the chain of transmission records must be searched. The isolated transmission record is then used to create a route output queue entry and a message information table. The normal output processing tasks then treat the message as they would any other, and read the message information block and the message from disc as they are needed.



Note: Each output channel has information of the same kind. The information for each channel is mixed on the disc with that for others.

FIG. 8—Relationship of retrieval information on disc

OPERATING EXPERIENCE

Three systems are in current use: the M110s, which have now had a microprocessor-based Telex interface added; the M150; and the Ferranti/Logica system. The M110s are simple units and have always given good performance. The M150, a much more complex machine, had operating difficulties initially, but now returns good performance figures despite fairly regular hardware failures. The Argus 700Es have not suffered any period of poor performance; some software failures have occurred, but these have been traced to a small number of causes. The hardware performance seems equally good for what must be considered an elderly minicomputer by current-day standards. The operating performance is summarised in Table 2.

The ILTMS service supports 70 customers with an average network size of 16 circuits. The largest network has over 110 circuits.

ACKNOWLEDGEMENTS

Thanks are due to Mr. C. E. Morgan for his help with historical information, to Mr. T. M. Day, Mr.W. Pettle and Mr. S. Miller for details of the performance record of ILTMS systems, and to Mr. M. Seaford for providing software documentation and more accurate dates for historical events.

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Institution of British Telecommunications Engineers

(formerly Institution of Post Office Electrical Engineers)

General Secretary: Until 30 November 1983—Mr. R. E. Farr, BT/TE/SES5.3, Anzani House, Trinity Avenue, Felixstowe, Suffolk, IP11 8XB; Telephone Felixstowe (0394) 271184 Extn. 7530; from 1 December 1983—Mr. J. Bateman, BT/NS3.2.3, Room 620, Williams National House, 11 – 13, Holborn Viaduct, London EC1A 2AT; Telephone 01 – 357 3858.

(Membership and other local enquiries should be directed to the appropriate Local-Centre Secretary as listed below)

CHANGE OF SECRETARY

Mr. R. E. Farr has given notice to Council of his wish to resign from the post of General Secretary of the Institution, having served for almost 6 years in that office. Council has appointed Mr. J. Bateman to succeed to the office from 1 December 1983.

MEMBERS ABOUT TO RETIRE

Members about to retire are reminded that they may secure life membership of the Institution at a once-and-for-all cost of £8·00. Retired members may enjoy all the facilities provided by the Institution, including a free copy of *British Telecommunications Engineering* posted to their home address.

Enquiries should be directed to the appropriate Local-Centre Secretary; members living in, or moving to, an area served by a different Centre from that to which they currently belong may find it more convenient to arrange a transfer to the new Centre's membership list before retirement in order to ensure advice on local activities.

R. E. FARR
Secretary

Local-Centre Secretaries

The following is a list of Local-Centre Secretaries, to whom enquiries about membership of 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. P. J. Thompson	British Telecom Midland HQ/PLT4.1, 245 Broad Street, Birmingham B1 2HQ 021–262 4287
Eastern (Bletchley)	Mr. D. R. Norman	British Telecom GMO/ED9.1, Telephone House, 25–27 St. John's Street, Bedford MK42 0BA (0234) 48299
Eastern (Colchester)	Mr. P. M. Cholerton	British Telecom East HQ/PLG2.1.4, St. Peter's House, St. Peter's Street, Colchester CO1 1ET (0206) 89547
East Midlands	Mr. D. W. Sharman	British Telecom GMO/ES3.3, 200 Charles Street, Leicester LE1 1BB (0533) 534409
London	Mr. L. J. Hobson	British Telecom HQ/RA1.5.2, Procter House, 100–110 High Holborn, London WC1V 6LD 01–432 2119
Martlesham	Mr. R. M. Brooks	British Telecom Research Laboratories, R9.2.4, Martlesham Heath, Ipswich IP5 7RE (0473) 643378
North Eastern	Mr. R. S. Kirby	British Telecom North East HQ/Plg.2.4.2, 36 Park Row, Leeds LS1 1EA (0532) 467362
Northern	Mr. L. G. P. Farmer	British Telecom GMO/I1.4, Swan House, Pilgrim Street, Newcastle-upon-Tyne NE1 1BA (0632) 613657
Northern Ireland	Mr. W. H. Tolerton	British Telecom GMO/EC1, Dial House, 3 Upper Queen Street, Belfast BT1 6LS (0232) 42444
North Western (Manchester and Liverpool)	Mr. W. Edwards	British Telecom North West HQ/F2.3, Telecommunications House, 91 London Road, Manchester M60 1HQ 061–863 7778
North Western (Preston)	Mr. R. L. Osborn	British Telecom GMO/LN4, Telephone House, Fenton Street, Lancaster LA1 1BA (0524) 88400
Scotland East	Mr. J. S. Ward	British Telecom Scotland HQ/P2.2.3, Canning House, 19 Canning Street, Edinburgh EH3 8TH 031–222 2510
Scotland West	Mr. G. A. Dobbie	British Telecom GMO/EX17, Marland House, 40 George Street, Glasgow G1 1BA 041–220 2365
South Eastern	Mr. S. J. Hurdle	British Telecom South East HQ/PL/EQ4.5, 52 Churchill Square, Brighton BN1 2ER (0273) 201188
South Western	Mr. D. P.Cosh	British Telecom South West HQ/Sv2.3.1, Mercury House, Bond Street, Bristol BS1 3TD (0272) 295578
Stone/Stoke	Mr. J. Coulson	British Telecom Technical College, IT7.2.1C, Stone ST15 0NQ (0785) 762381
Wales and the Marches	Mr. D. A. Randles	British Telecom Wales and the Marches HQ/PW3.1.2.2, 25 Pendwyallt Road, Cardiff CF4 7YR (0222) 391370

Notes and Comments

INCREASE IN SUBSCRIPTION RATES

The Board of Editors regrets that the price of the *Journal* will increase from the January 1983 issue. The new price will be 90p (£1·40 including postage and packaging) (Canada and the USA $12·00). The special price to British Telecom and British Post Office Staff remains at 48p per copy.

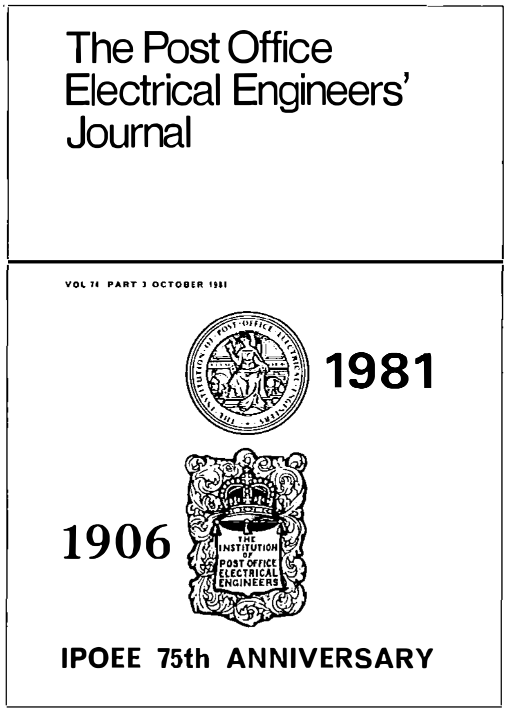
JANUARY 1982 ISSUE

The editors would very much appreciate the return of spare and unwanted copies of the January 1982 issue of the *Journal* (Vol. 74, Part 1). Surplus copies, complete with model-answer *Supplement* and annual index, should be returned to British Telecommunications Engineering Journal (Sales), Ground Floor Lobby, 2–12 Gresham Street, London EC2V 7AG.

OCTOBER 1981 SPECIAL ISSUE

The October 1981 special issue contains articles on the following topics:

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS
TELECOMMUNICATIONS AND SOCIETY
THE INLAND NETWORK
INTERNATIONAL SERVICES
SWITCHING AND SIGNALLING
MECHANICAL AND CIVIL ENGINEERING
CUSTOMER APPARATUS
TRANSMISSION
POSTAL ENGINEERING
RESEARCH
THE FUTURE



The October 1981 issue of the *Journal* was a special double-size issue to mark the 75th Anniversary of the Institution of Post Office Electrical Engineers. The issue reviews many of the changes that have taken place in telecommunications and postal services since 1956.

Copies of the issue are still available, price £1·30 each, including post and packaging (the cost to British Telecom and British Post Office staff is 48p).

If you wish to order copies, please complete the order form below and send it to the address shown. (Cheques and postal orders, payable to *'BTE Journal'*, should be crossed "& Co." and enclosed with the order. Cash should not be sent through the post.

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Please state with which issue you wish your subscription to commence (April, July, October or January) ....

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Any member who does not have a copy of the catalogue can obtain one on loan from the Librarian, IBTE, 2–12 Gresham Street, London EC2V 7AG. Library requisition forms are also available from the Librarian, from honorary local-centre secretaries, and from Associate Section centre secretaries and representatives.

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The *Journal* is published quarterly in April, July, October and January, at 80p per copy (£1·30 per copy including postage and packaging); annual subscription: £5·20; Canada and the USA: $12·00.

The price to British Telecom and British Post Office staff is 48p per copy.

Back numbers will be supplied if available, price 80p (£1·30 including postage and packaging). At present, copies are available of all issues from April 1974 to date with the exception of the April and October 1975; January, April and October 1976; and January 1982 issues.

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Employees of British Telecom and the British Post Office can obtain the *Journal* through local agents.

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Readers can have their copies bound at a cost of £8·75, including return postage, by sending the complete set of parts, with a remittance, to Press Binders Ltd., 4 Iliffe Yard, London SE17 3QA.

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European customers can pay by means of a direct bank mail transfer. Customers using this method of payment should instruct their bankers to remit payments to the *Journal's* bankers—Midland Bank plc, 2 Gresham Street, London, EC2V 7JD, England—specifying that the beneficiary is to be *British Telecommunications Engineering Journal*.

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Correspondence relating to the distribution and sales of the *Journal* should be addressed to *British Telecommunications Engineering Journal* (Sales), Ground Floor Lobby, 2–12 Gresham Street, London EC2V 7AG.

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With the exceptions indicated, all communications should be addressed to the Editorial Office, *British Telecommunications Engineering*, IDP5.1.1, Room 704, Lutyens House, Finsbury Circus, London EC2M 7LY (Telephone: 01-357 4313).

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All enquiries relating to advertisement space reservations should be addressed to Mr. A. J. Pritchard, The Advertisement Manager, *British Telecommunications Engineering Journal*, Room 608, 2–12 Gresham Street, London EC2V 7AG.

Model-Answer Books

Books of model answers to certain of the City and Guilds of London Institute examinations in telecommunications are published by the Board of Editors. Copies of the syllabi and question papers are not sold by *British Telecommunications Engineering Journal*, but may be purchased from the Sales Department, City and Guilds of London Institute, 76 Portland Place, London W1N 4AA.

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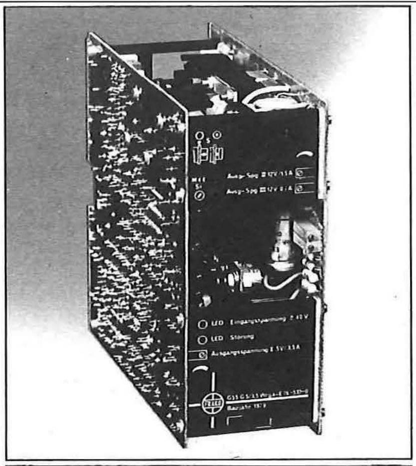

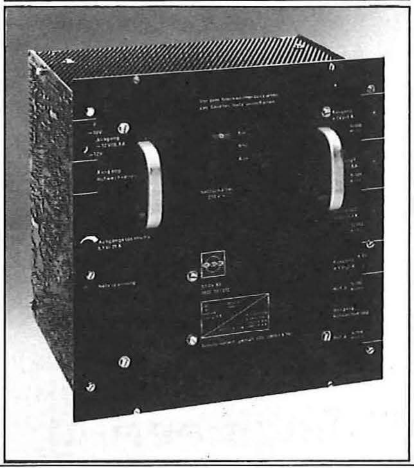

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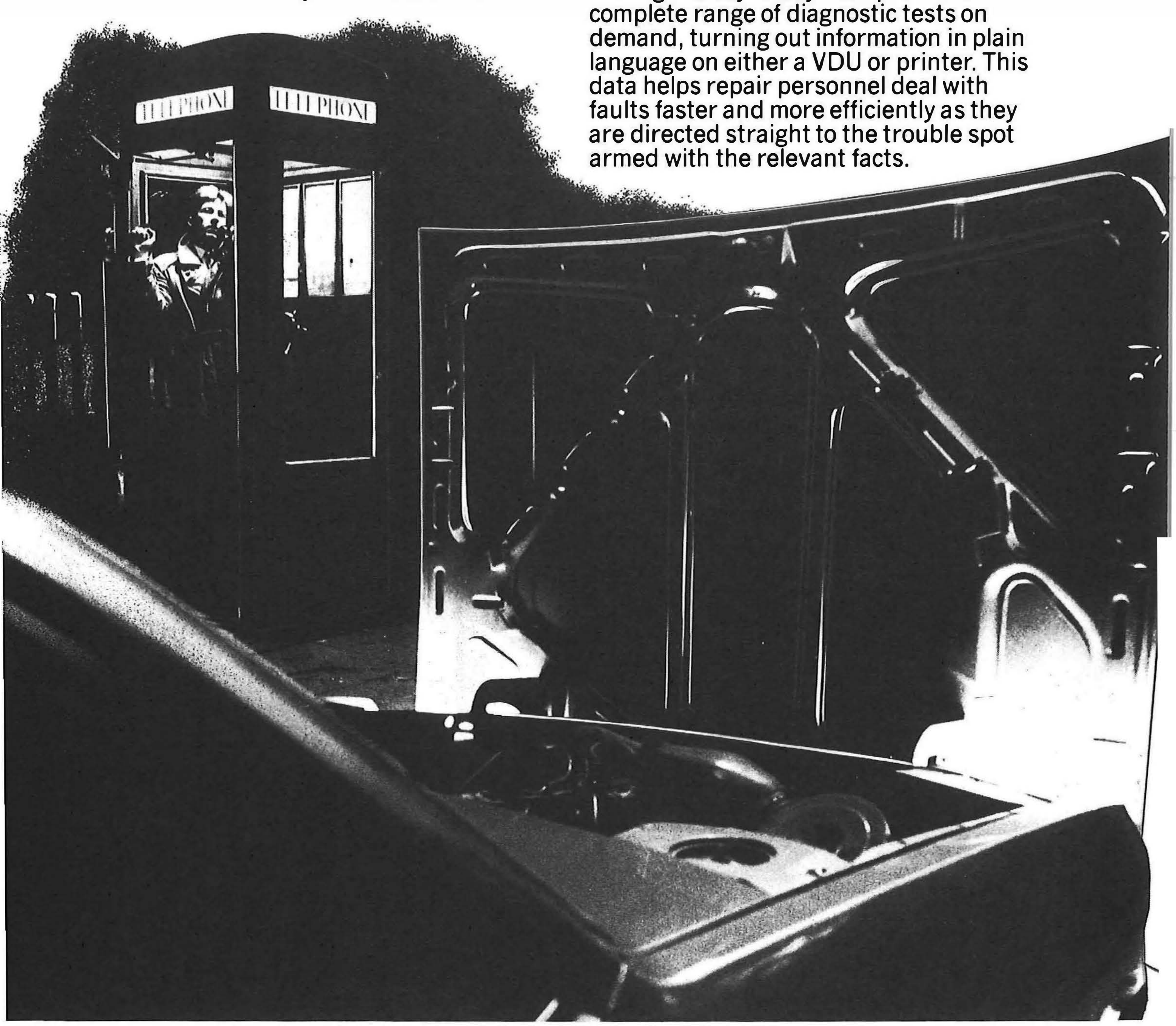


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TMC policy is to exploit to the full advanced electronic techniques in the development and manufacture of the most effective cost/performance products for administrations and users throughout the world.

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KT1 Series. Designed as an economic plug-in alternative to rotary dial telephones, the low cost TMC KT1 Series pushbutton telephone incorporates the results of several significant steps forward in technology. A single custom designed integrated circuit provides both transmission and signalling facilities. Simple construction, a single PCB, and a policy of replacement (rather than repair on subscriber's premises) all contribute to low maintenance costs. By designing-out major fault-prone areas, such as the carbon microphone and the mechanical dial, TMC has ensured a high MTBF. Both table and wall-mounting models are available, as well as LD and MF versions.

KT4. Based upon the proven circuitry of the KT1 Series, the KT4 has a low-profile case. Incorporating all the economic and technical advantages of the KT1 Series, the TMC KT4 is a fully electronic telephone suitable for installation in direct exchange lines and extension plan arrangements – without the need to dismantle the case. Other features include plug-in installation and a calling volume control.

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KBX is an integrated range of electronic small business communications systems based upon the new 'hybrid' concept of combined key system and PABX operation. Meeting the needs of small-to-medium sized businesses, the KBX range extends from one exchange line and three extensions up to 100 ports. In addition, KBX systems provide a wide selection of programmable facilities.

KBX 3 and 6. These systems combine the facilities of chief/secretary operation with the flexibility of a key system. Featuring the high levels of reliability inherent in custom designed integrated circuit technology, TMC KBX 3 (1 +3) and 6 (2 + 6) systems meet the needs of the smallest business and professional user, as well as those of a branch or department of a larger concern. In addition, they offer many other advantages – such as easy installation and operation, low maintenance, simple and rapid 'programming-in' of facilities at the Central Control Unit, and unrivalled value-for-money performance.

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Known as the SSU, this electronic sub-system enhances and upgrades existing electro-mechanical main exchanges, by providing additional facilities and services which would normally be available only with SPC electronic switching systems. When the SSU is installed, existing equipment can give many more years of useful service. In addition, a more economically and technically acceptable transition to fully electronic systems can be achieved.

For more information about TMC telephone instruments, systems, or the SSU, contact:

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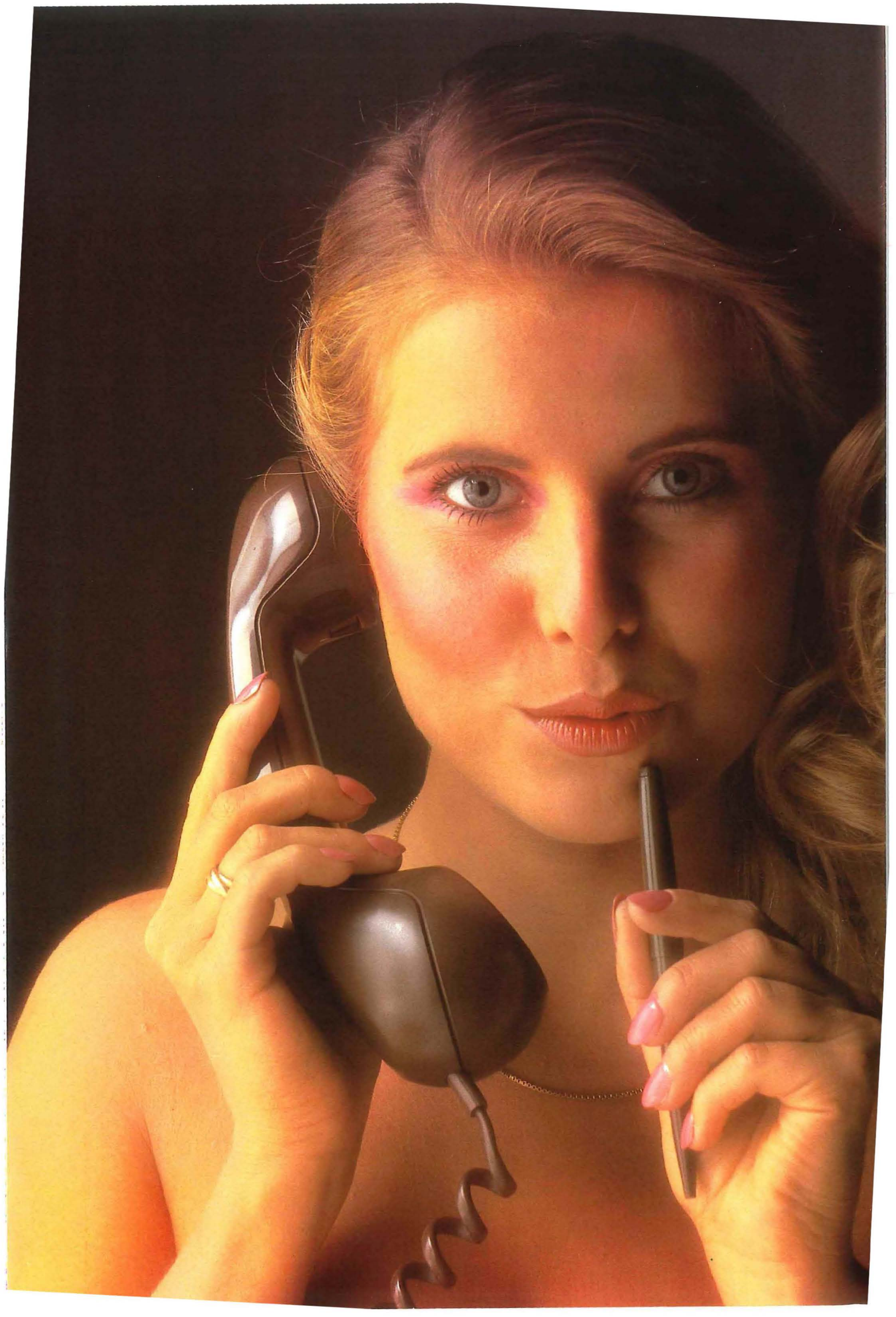

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GEC offers a comprehensive range of digital switching and transmission systems for rural, national and international networks.

'System X', Britain's digital switching system, has a flexible architecture designed to meet the rapidly changing needs of communications networks throughout the world. State-of-the-art technology based on continuous in-depth research and development ensures that 'System X' is as suited to providing the sophisticated services and facilities of the future as it is to enhancing and overlaying existing networks from local to international gateway levels. Designed for world markets GEC's 'System X' embodies the experience of British Telecom, one of the world's largest operating administrations, and the skills of Britain's biggest electrical and electronics manufacturer.

GEC also produces UXD5, an economic stand-alone exchange for small-capacity rural and suburban use, which is compatible with all types of digital and analogue exchanges. An enhanced version of UXD5 incorporates a 2GHz, 8Mbit/s microwave system within the same equipment cabinet.

The GEC range of broadband microwave transmission systems includes an 11GHz, 140Mbit/s system which is being used by British Telecom to overlay the whole of the UK network. The range also includes 4 and 6GHz, 140Mbit/s trunk systems and 19GHz, 8 and 140Mbit/s roof-mounting systems for metropolitan applications.

GEC has extensive experience in the design, manufacture and installation of optical fibre systems which have been supplied to both UK and overseas customers. The current range of optical fibre systems features multimode and monomode equipment for operation at bit rates up to 140 Mbit/s.

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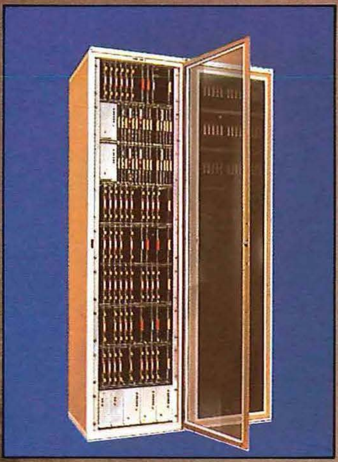

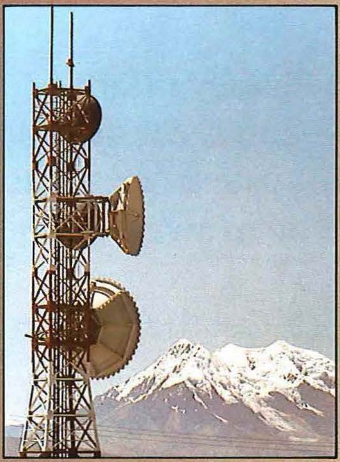

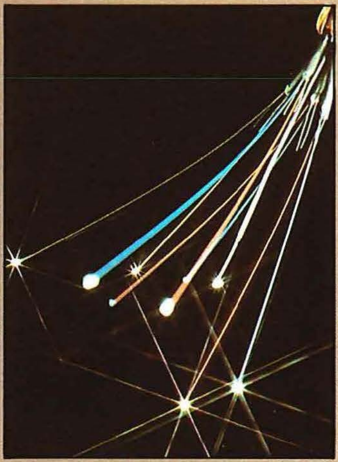

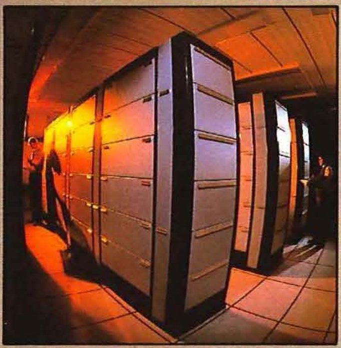

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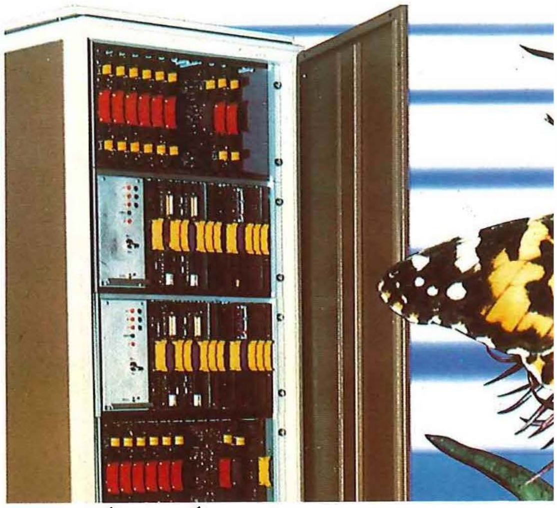

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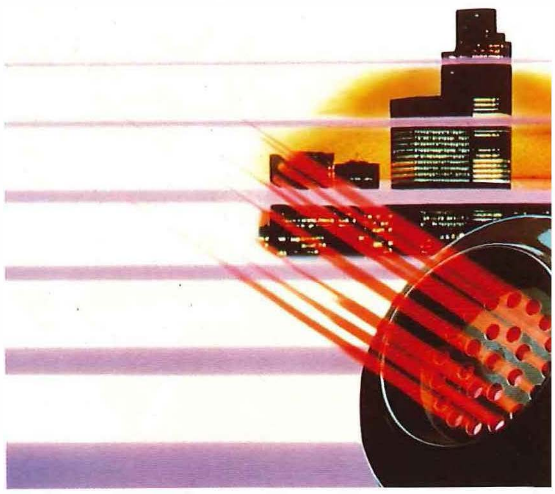

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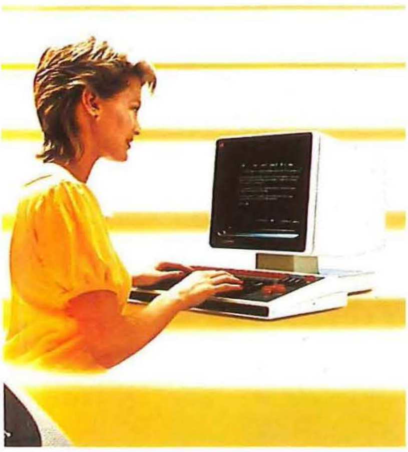
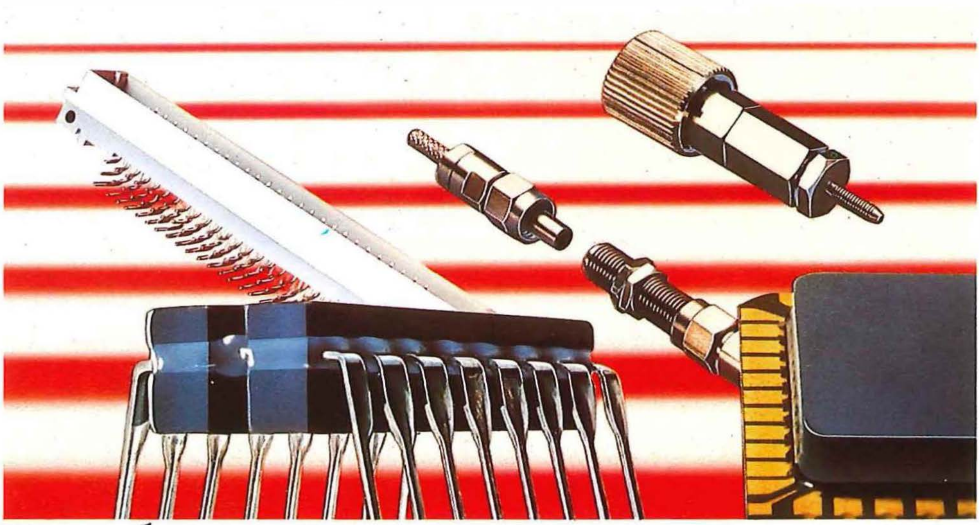
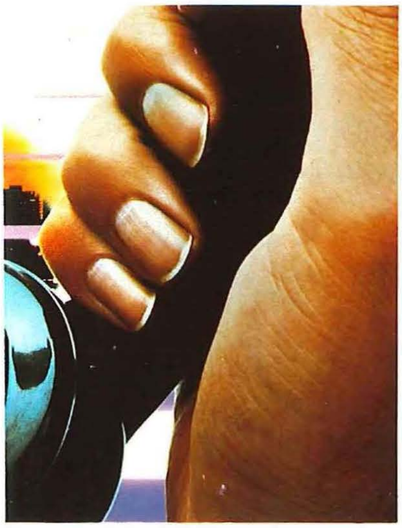


Business exchange

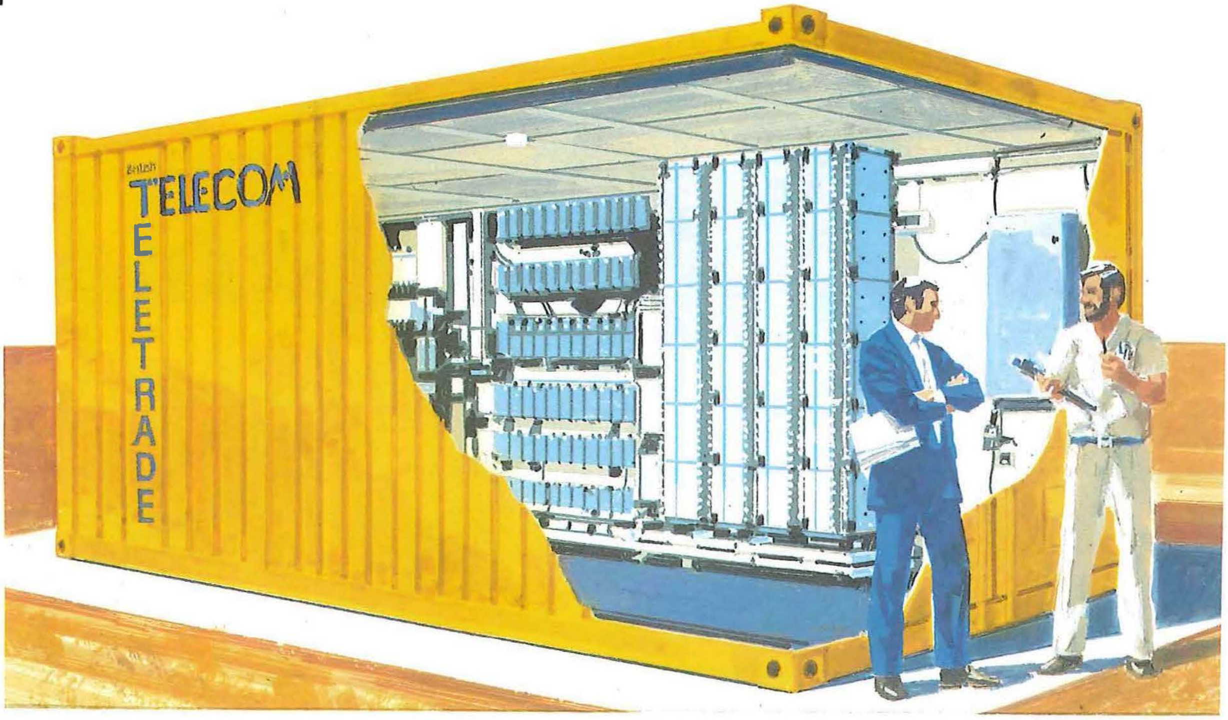


ICs and connectors



Data networks

Instant phone service



British Telecom Strowger exchanges are now available, in containerised form, at extremely economical rates.

Each unit comes complete, even down to its own tools, test equipment and spares. It only requires connection to a suitable power source and it's a working exchange.

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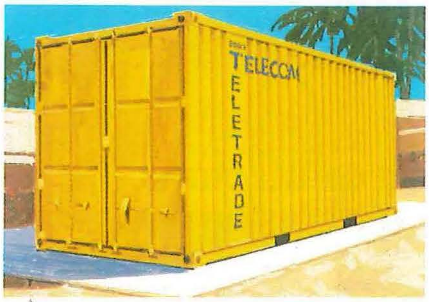
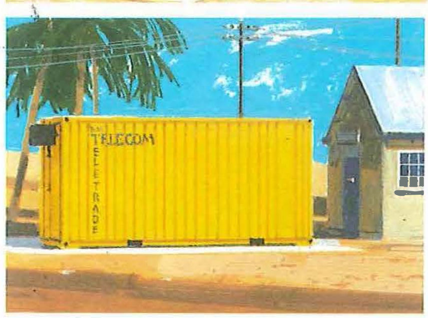
The system is based on a unit of 400 lines, which can be quickly expanded to 900 lines, or 800 if tandem





switching facilities are required. Further units can be added to bring the exchange capacity up to 2,700 lines (6 units) or 5,400 lines (12 units).

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All equipment comes from British Telecom's factories department and is fully tested and adjusted for immediate use. British Telecom, as one of the world's largest stockholders of telecommunication equipment, can supply a range of Strowger equipment in addition to complete exchanges. And British Telecom can guarantee a supply of spares for 10 years.

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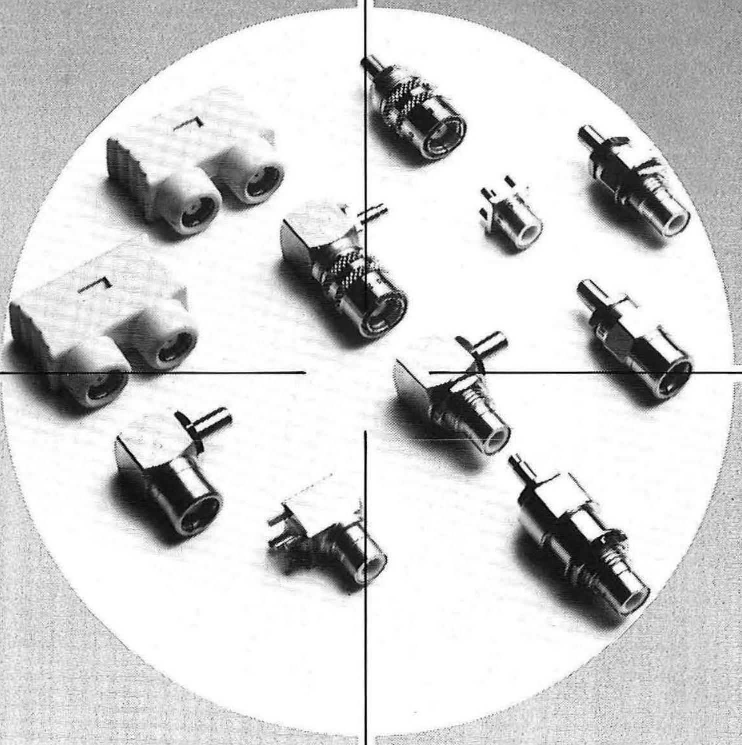
The Greenpar range of 75 ohm BT 43 series connectors is approved to both BT 8003 and BS 9210F0022, certifying conformity of design and providing user confidence in quality, performance and reliability. Cost effective design plus the latest computer test technology ensures complete product integrity whilst continuity and volume supply is assured by our fully automated manufacturing and assembly procedures.
The BT 43 family of connectors comprises the following:
U link, featuring a robust Noryl body designed for ease of use and long life; straight and right angle PB and cable crimp types both designed for ease of assembly and with either snap-on or latching engagement. The latching connector, which prevents accidental disconnection, is preferred for most applications.



BT/Greenpar/British Standard cross reference

BT 43 series

BT	Greenpar	B.S. Style	Cable
Straight Crimp Sockets			
43/1A	G67241D280	06-03-1B1-C	2001
43/2A	G67241D117	06-03-1B2-Q	2002
43/3A	G67241D62	06-03-1B3-R	2003
43/4A	G67241D22	06-03-1BB-B	RG179B/U
Straight Latching Crimp Sockets			
43/1B	G67243D280	06-03-2B1-C	2001
43/2B	G67243D117	06-03-2B2-Q	2002
43/3B	G67243D62	06-03-2B3-R	2003
43/4B	G67243D22	06-03-2BB-B	RG179B/U
Right Angle Latching Crimp Sockets			
43/1C	G67244D280	08-03-2B1-C	2001
43/2C	G67244D117	08-03-2B2-Q	2002
43/3C	G67244D62	08-03-2B3-R	2003
43/4C	G67244D22	08-03-2BB-B	RG179B/U
Right Angle Crimp Sockets			
43/1D	G67242D280	08-03-1B1-C	2001
43/2D	G67242D117	08-03-1B2-Q	2002
43/3D	G67242D62	08-03-1B3-R	2003
43/4D	G67242D22	08-03-1BB-B	RG179B/U
Straight Bulkhead Crimp Plugs			
43/1A	G67245D280	07-02-1B1-C	2001
43/2A	G67245D117	07-02-1B2-Q	2002
43/3A	G67245D62	07-02-1B3-R	2003
43/4A	G67245D22	07-02-1BB-B	RG179B/U
Right Angle Bulkhead Crimp Plugs			
43/1B	G67249D280	11-02-B1-C	2001
43/2B	G67249D117	11-02-B2-Q	2002
43/3B	G67249D62	11-02-B3-R	2003
43/4B	G67249D22	11-02-BB-B	RG179B/U
Straight 5 mm Bulkhead Mount Plugs			
43/1C	G67247D280	07-02-2B1-C	2001
43/2C	G67247D117	07-02-2B2-Q	2002
43/3C	G67247D62	07-02-2B3-R	2003
43/4C	G67247D22	07-02-2BB-B	RG179B/U
Straight PCB Mounting Plug			
43/1D	G67207	13-02	
Right Angle PCB Mounting Plug			
43/1E	G67210	14-02	
U Link			
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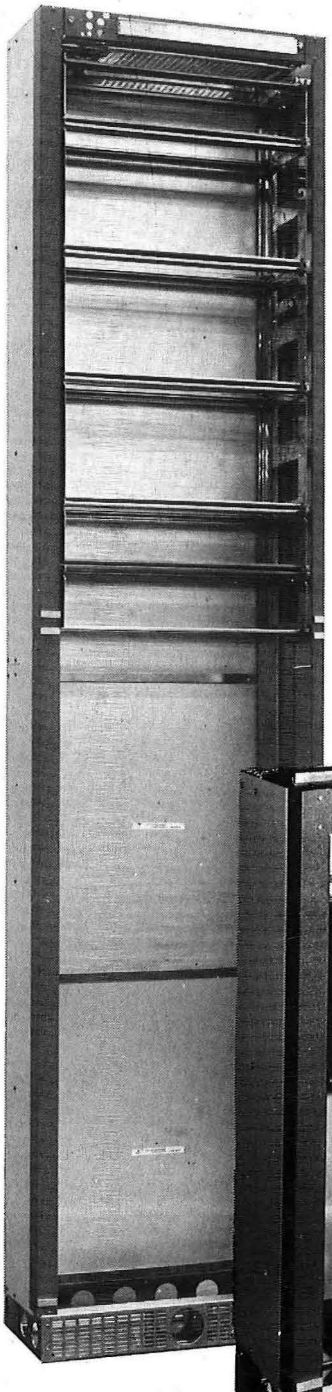

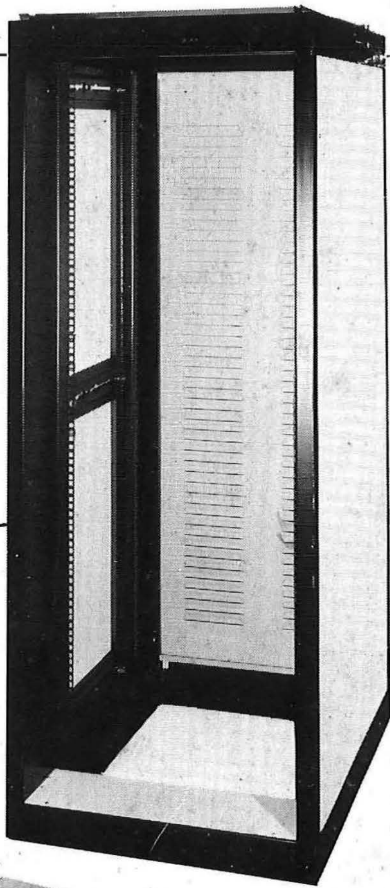

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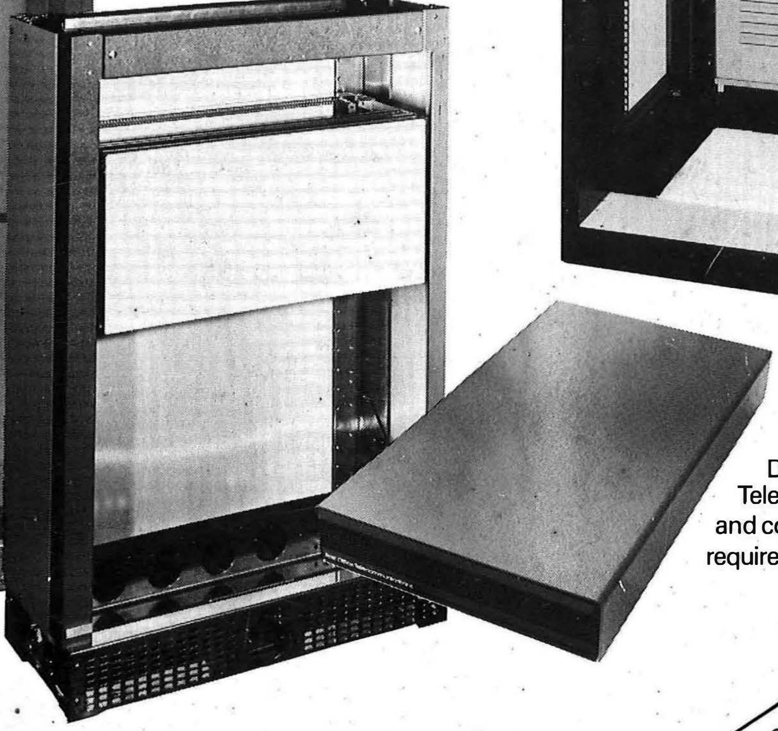

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Rack 80A, 8- and 4-unit shelves in full production. Detailed leaflet on request.

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