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43/4C	G67244D22	08-03-2BB-B	RG179B/U
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43/4A	G67245D22	07-02-1BB-B	RG179B/U
Right Angle Bulkhead Crimp Plugs			
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43/2B	G67249D117	11-02-B2-Q	2002
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43/4C	G67247D22	07-02-2BB-B	RG179B/U
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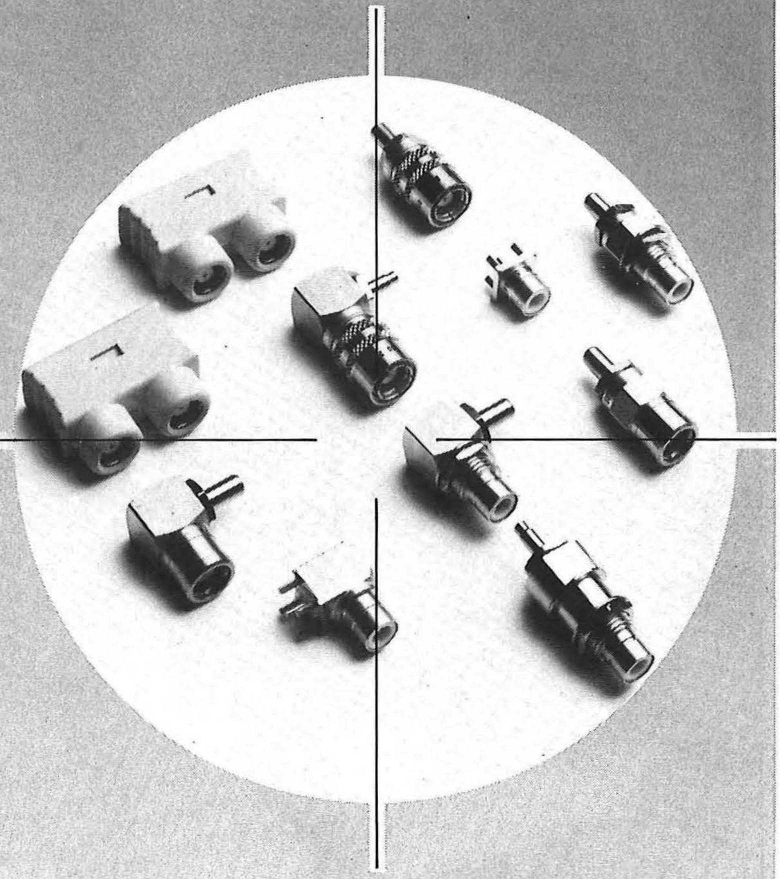
43/1E	G67210	14-02	
U Link			
13A	G67229	33-05	



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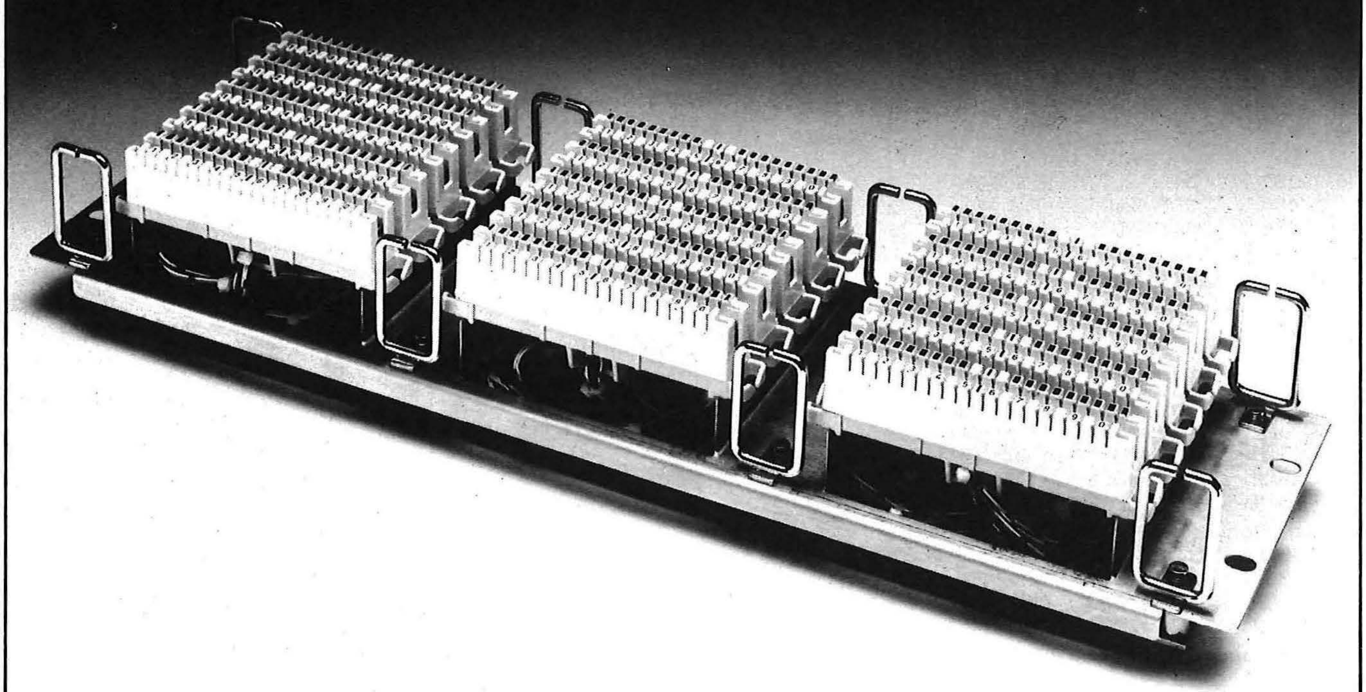

British Telecommunications Engineering

EDITORIAL

The provision of local broadband cable networks in the UK was recommended in the Hunt Report published in October last year. The report envisages the provision of cable distribution systems carrying about 30 channels mainly for entertainment purposes in order to attract the initial investment for the network and to establish the necessary base for future interactive services. To the telecommunications engineer, however, the main interest is in the networks themselves and the way in which they will evolve. These local networks represent a massive investment and must be able to cope with the changing demand for new services over their lifetimes of some 20-30 years. Thus, the type of network should be capable of being developed into a form suitable for any future advanced services. Also, the local networks should be considered as elements of an overall information-technology infrastructure; therefore, the technical and operating standards for the individual systems will need to be devised in such a way as to facilitate the interconnection of these networks. These are the challenges presented to the telecommunications engineer. Already, British Telecom has installed a trial optical-fibre cable network in Milton Keynes to assess the implications of this new technology. An article on p.205 of this *Journal* discusses the requirements of a multi-service cable distribution system and briefly describes the Milton Keynes trial system.

Optical-Fibre Transmission Systems in the British Telecom Network: An Overview

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UDC 621.391.63:666.189.2

British Telecom (BT) has taken a leading role in the research and development of optical-fibre transmission and has established a worldwide reputation in this most important new technology. Fully operational systems are already in service in the network and BT has formulated plans for the extensive use of optical fibres in the future. By the end of the 1980s, 50% of the main network alone will be optical-fibre systems and the junction network is expected to be using such systems for the longer routes. Studies are in hand for the utilisation of optical fibre in the local network. Transatlantic submarine systems, using optical fibres are expected in the late-1980s. This article gives a general overview of the technology and BT network applications.

INTRODUCTION

In the late-1950s, the invention of the laser meant that optical communication was fast becoming a possibility. The use of optical frequencies around 300 000 GHz (about 1000 nm wavelength) gives rise to enormous potential for the transmission of information, but before any practical long-distance system could be developed, some form of optical waveguide was necessary because optical transmission through the atmosphere is generally found to be too unreliable. Various proposals were put forward including a suggestion for a gas-filled pipe either with lenses placed at regular intervals to recollimate the beam or with flowing gas[1].

None of these proposals represented practical arrangements, but in 1966 Kao and Hockham[2] suggested that a thin dielectric circular waveguide in the form of a glass fibre offered a practical solution if the attenuation of the glass could be made very low. At that time, the attenuation of the purest glass was in excess of 1000 dB/km and elementary calculations suggested that a figure of 20 dB/km would be necessary for a practical system. In the late-1960s, possible glass formations were identified and, in 1970, the first 20 dB/km glass fibre was announced. Extensive development work since that time has dramatically reduced fibre attenuation and today experimental fibres with losses less than 0·5 dB/km can be realised. Development of optical components was also extremely rapid and, by the early-1970s, many laboratories around the world were well advanced in experimental optical-fibre communications.

British Telecommunications Research Laboratories (BTRL) had commenced studies in the mid-1960s and from this early base established the world-wide reputation in this technology which it enjoys today. By 1974, work had reached the point where practical field trials were the natural next step. By 1977, BTRL had successfully established a trial route between Martlesham and Ipswich operating at 8 Mbit/s and 140 Mbit/s. About the same time, Standard Telecommunications Laboratories successfully established a trial 140 Mbit/s route between Hitchin and Stevenage.

From that date BT has moved rapidly to take advantage of optical-fibre systems, which may be summarised as having

(*a*) very large information capacity;
(*b*) potentially low material costs;
(*c*) small cable size;
(*d*) negligible crosstalk;
(*e*) high immunity to interference;
(*f*) complete electrical isolation; and
(*g*) large repeater spacings.

Today, BT is possibly the most advanced Administration in the world in the exploitation of optical-fibre systems in its network. In this article, a general overview of BT's activities since 1977 is given. Further articles in this *Journal* will give more detailed considerations to this most significant change in transmission technology since the invention of the transistor. First, however, a necessarily brief review of the essential features of the technology is given.

OPTICAL-FIBRE SYSTEM TECHNOLOGY

Optical-Fibre System Principles

Fig. 1 shows, in a simplified form, a basic optical-fibre system employing buried intermediate regenerators. Although analogue systems can be realised, BT's plans for a digital transmission network meant that most optical-fibre developments have been in digital form.

The electrical parts of the system are very similar to digital transmission systems used on coaxial cable[3]. An optical-fibre system consists of transmit and receive terminals and may have intermediate regenerative repeaters along the route. The regenerator spacing, however, is much greater than on coaxial cables; for example, at 140 Mbit/s spacings of 10 km can be achieved with optical-fibre systems compared with 2 km on coaxial cable. In the laboratory, however, spacings in excess of 100 km at 140 Mbit/s over optical fibre have already been announced.

The main feature of an optical-fibre system is that there is a light source at the transmit end (either a laser or light-emitting diode (LED)), an optical-fibre transmission path, and a light detector at the receive end.

Transmission Principles

Optical fibres guide light by means of the reflection that occurs at the boundary of glasses of different refractive index[4]. Optical fibres may be classified according to their refractive index profile into 2 types: namely,

(*a*) step-index fibres, and
(*b*) graded-index fibres.

Fig. 2 shows the various fibre geometries.

Step-Index Fibre

The step-index fibre has a circular cross-section with a core of glass of refractive index n_1 and an outer cladding of glass with a lower refractive index n_2. The fibre is typically 125 μm (about 0.005 in) diameter. Light launched into the core at

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† Trunk Services Department, British Telecom Inland

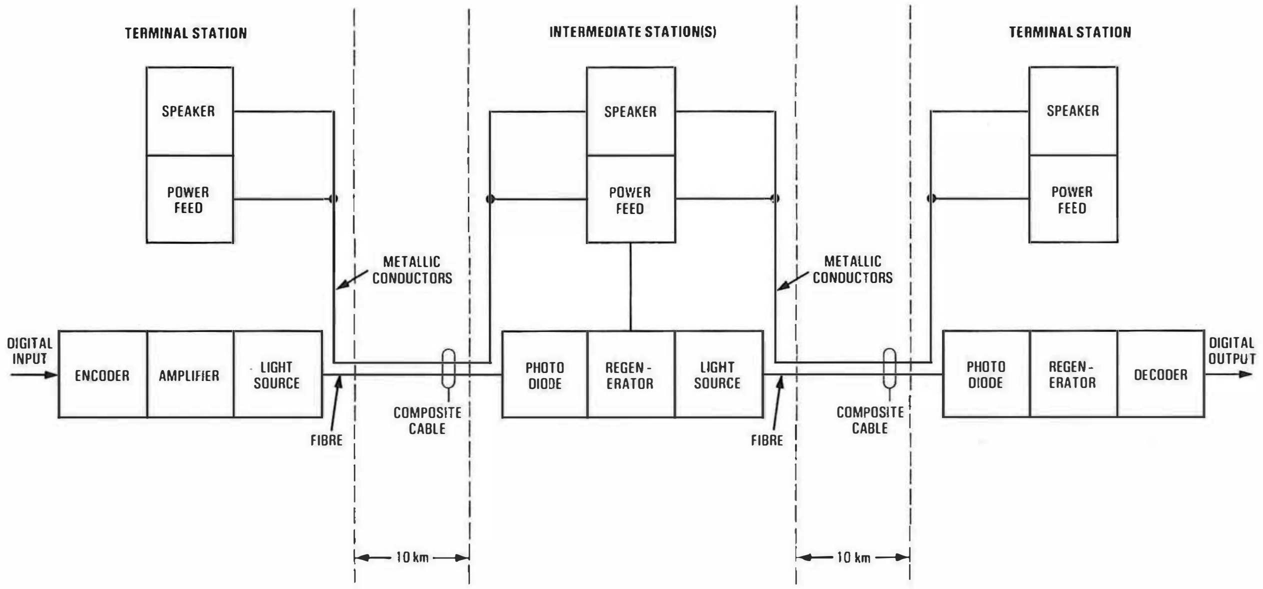


FIG. 1—Simplified block diagram of a 140 Mbit/s multimode optical-fibre system

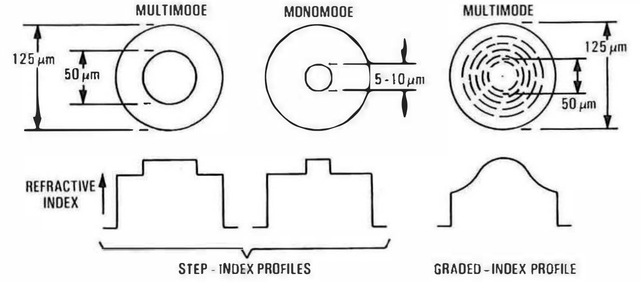
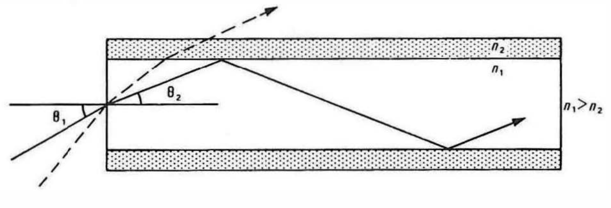
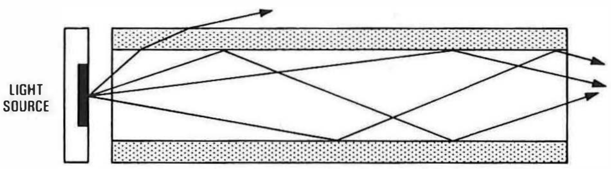


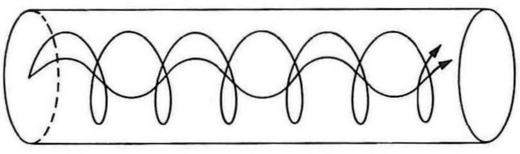
FIG. 2—Fibre geometry



(*a*) Ray diagram of a step-index fibre



(*b*) Launch conditions into a step-index fibre showing generation of multiple modes



(*c*) Mode propagation in graded-index fibre

FIG. 3—Ray propagation in optical fibres

angles up to θ_1 is propagated within the core at angles up to θ_2 to the axis (see Fig. 3(*a*)). Light launched at angles greater than θ_1 is not internally reflected and is refracted into the cladding or possibly out of the fibre. The maximum launch angle, θ_1, and the propagation angle, θ_2, for propagation of the ray along the fibre are expressed as a function of the theoretical numerical aperture, *NA*, where

$$NA = (n_1^2 - n_2^2)^{1/2} = \sin\theta_1 = n_1 \sin\theta_2.$$

The fibre is an electromagnetic waveguide and only certain modes (which may, for simplicity, be regarded as rays) corresponding to specific values of θ_2 can be propagated (see Fig. 3(*b*)). The number of possible modes, or rays, for light at any one wavelength is determined by the *NA* and the diameter of the core. The smaller the diameter of the core, the fewer modes are propagated. When the diameter of the core is the same order as the wavelength of the light then only a single mode propagates; thus, step-index fibres may be further classified into

(*a*) multimode fibres; and
(*b*) monomode fibres.

For light to be launched efficiently into a fibre, the active area of the light source should not be greater than the diameter of the core. Even so, only a portion of the light emitted from the source strikes the fibre at the required angles less than θ_1. The higher the value of *NA* of the fibre, the more efficient is the coupling. Unfortunately, the higher the value of *NA*, the larger is the number of modes that can propagate the length of the fibre, and this gives rise to problems of dispersion.

Dispersion

Different modes have to travel different distances along the fibre and, therefore, arrive at the far end at different times. This effect is known as ***multipath dispersion*** and means that a pulse of light injected into the fibre spreads in the time domain at the far end. In the frequency domain, this implies that the bandwidth of the fibre reduces with length of fibre[5]. Also, the bandwidth decreases with the increase in value of *NA*. Typical values of *NA* for optical fibre for long-distance application is 0·2, but for short data links a value as large as 0·5 can be tolerated.

Another dispersion effect is caused by the material of the glass itself. This *material dispersion* occurs because the refractive index of the medium determines the velocity of propagation and this in turn varies with the wavelength of the injected light. This can be a problem when the light sources have wide spectral spreads.

Clearly, material-dispersion effects can be minimised by using light sources of narrow line widths such as lasers and/or operating at wavelengths of minimum material dispersion. The effect of multipath dispersion can be minimised by reducing the core size so that only one mode can propagate, or by using graded-index fibre.

Monomode fibres have theoretically the widest bandwidth and largest information capacity, but because of the extremely small diameter of the core (typically 7–8 μm at present) they originally presented some practical problems in jointing the cable and in launching the light into the core, although these have now been overcome.

Graded-Index Fibres

The problem of multipath dispersion can be reduced by replacing the step-index cross-section with one where the refractive index of the glass varies continuously from a maximum at the axis to a lower level at the fibre boundary. Although many modes (typically 250–300) are propagated (see Fig. 3(*c*)), the modes that travel furthest in the outer regions of the fibre in a region of lower refractive index travel faster than those travelling along the axis. The net effect is that the modes, although travelling different path lengths, travel at different speeds and arrive with minimal pulse dispersion. To date, most optical-fibre systems in operational service have therefore used graded-index fibre to achieve high information transmission capacities.

Fibre Attenuation

The transmission loss due to the fibre is of equal importance to the dispersion or bandwidth problem. Losses occur as a result of absorption, scattering and radiation.

Absorption losses arise because of the presence of impurities in the glass. For example, the presence of water in the glass gives rise to harmonics of vibration which produce absorption losses in the wavelength bands of interest.

There are 2 main types of scattering mechanisms. The first, Rayleigh scattering, is caused by inhomogeneities of the material. Rayleigh scattering loss is inversely proportional to the fourth power of wavelength and hence fibre attenuation reduces with increasing wavelength (see Fig. 4).

The other type of scattering is caused by irregularities of the core-cladding interface which are formed in the fibre fabrication process. These irregularities mean that rays are not reflected at the same angle. This gives rise to mode mixing.

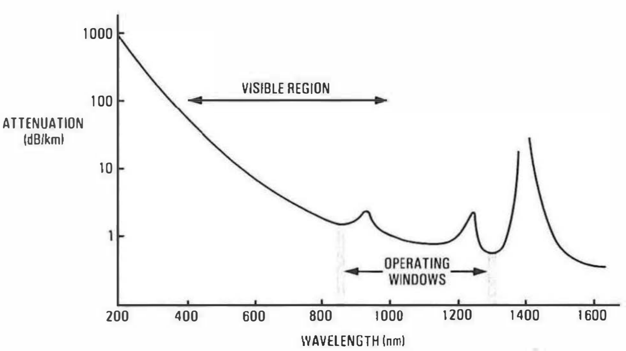


FIG. 4—Typical fibre loss characteristics

Radiation losses can arise from sharp bends in the fibre. When the fibre is bent, the field on the outside of the curve is forced to move faster to keep up with the field in the core. At certain distances from the core, the outside field is forced to move faster than the velocity of light, which it then resists by radiating light energy away. The critical radius of bending at which this occurs is very small. A particular problem known as *microbending*[1] arises from sinusoidal perturbation of the fibre lay in a cable and places constraints on the cable design and manufacture to ensure that fibres are housed in such a way as to avoid this effect.

Fibre Manufacture

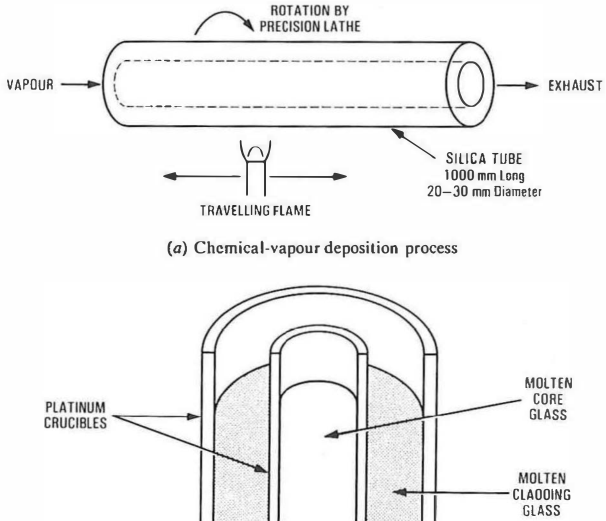
Optical fibres are manufactured by 2 basic techniques:

(*a*) chemical-vapour deposition (CVD); and
(*b*) the double-crucible method.

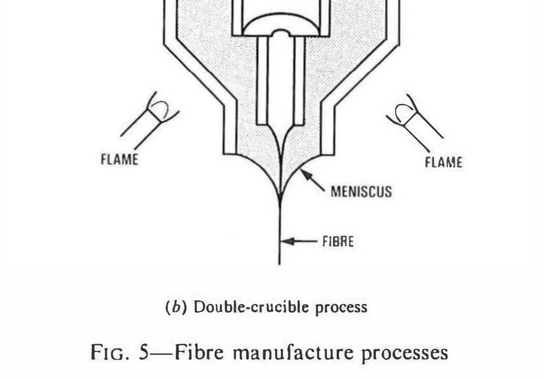
The CVD process is the most widely used for high-quality fibres, whereas the double-crucible method is a very economic arrangement for lower-grade fibres.

In the CVD method, a tube of extremely pure silica glass about 1 m in length is placed in a very precisely controlled lathe incorporating a furnace which can be made to traverse along the glass tube. During the traverses of the furnace, controlled dopants are allowed to flow through the centre of the tube (see Fig. 5(*a*)). After a predetermined number of passes of the furnace—usually about 30—the dopants form a layer of glass on the inside of the tube. By raising the temperature of the furnace, the tube can then be arranged to collapse into a solid glass rod, or preform, with a very precise cross-section in terms of refractive index.

The next stage is to transfer the prepared preform to a drawing furnace. The preform is held vertically and heated at its tip such that a filament of fibre can be drawn downwards at a very accurately controlled rate. This filament, which is



(*a*) Chemical-vapour deposition process



(*b*) Double-crucible process

FIG. 5—Fibre manufacture processes

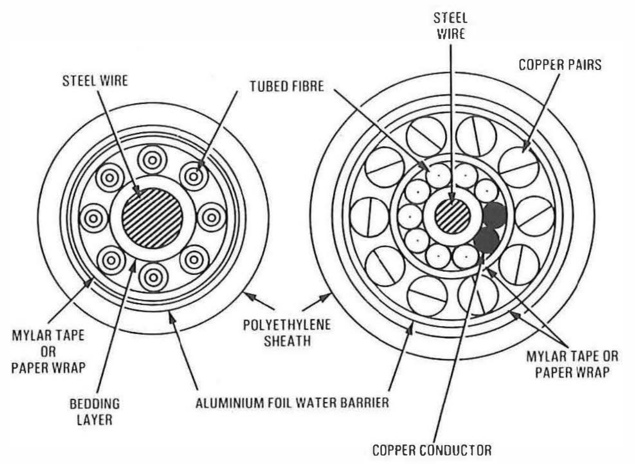


FIG. 6—Typical optical-fibre cable construction

now basically the fibre, is immediately coated with a protective coating before being reeled up ready for transfer to the cable-making plant. Before being formed up into a cable, the fibre is given a secondary protective coating, either closely bound onto the fibre or in the form of a loose tubing. This is necessary to minimise the problem of microbending.

There are a number of refinements to the basic CVD process including plasma deposition and an outside deposition process.

The double-crucible manufacturing process, which was developed by BTRL at Martlesham, is based on 2 accurately-controlled concentric crucibles containing core and cladding glass in a molten state from which the fibre is drawn. It has the principal advantage of being a continuous process compared with the CVD arrangement previously described. It is particularly useful for the production of low-cost lower-grade fibre (see Fig. 5(*b*)).

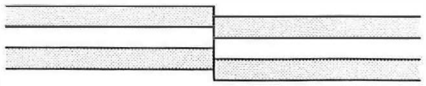
The design of optical-fibre cables—a seemingly simple problem—is one of the most challenging aspects in the use of this new technology. Fig. 6 shows some typical cable designs in use in the BT network. To date, it has been convenient to have cables of 8 fibres, together with associated copper wires and a central strength member. The copper wires are necessary to provide power feeding to any dependent regenerators and to provide speaker and supervisory facilities. The central strength member is necessary because during pulling operations and during the life of the cable it is essential that little or no strain is transmitted onto the fibres themselves.

Fibre Jointing

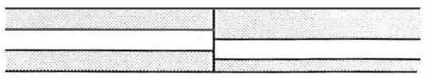
As stated previously, regenerators may be spaced at intervals of 10 km or more and it is clearly not practical to pull in cables of this length in one operation. Typically, cables are manufactured in lengths of about 1–2 km and, therefore, the fibres must be joined together in the field.

To effect a fibre joint, the ends of the fibre must be cut squarely, cleanly and butt together accurately. Great care and accuracy is necessary to avoid excessive losses and other transmission imperfections resulting from fibre joints (see Fig. 7), and much research has been carried out into optimum methods for effecting the fibre joint.

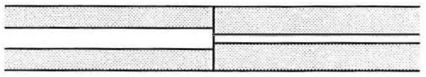
Mechanical jointing techniques were the early favourites; these depended on the accurate alignment of the outer diameters of the 2 fibres to ensure the alignment of the core carrying the light energy. A typical technique uses an accurately machined V-groove to achieve this alignment (Fig. 8). The fibres are brought into close proximity and often a small quantity of fluid to effect index matching is added. The fibres may be sealed into position using an epoxy resin or clamped by some other means. A variation of this technique is to use 3 accurately-machined stainless-steel rods to align the fibres.



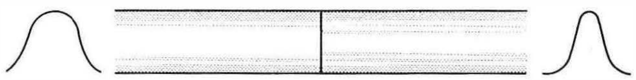
(*a*) Fibre misalignment



(*b*) Core off centre



(*c*) Different core sizes



(*d*) Different core profiles (graded-index)

FIG. 7—Some causes of jointing problems

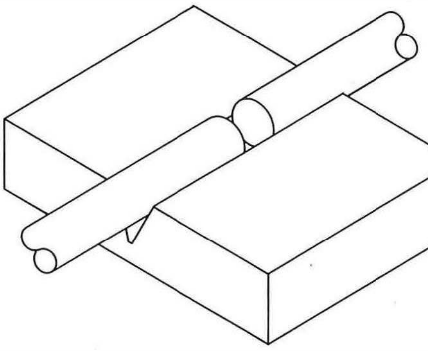


FIG. 8—Principle of the V-groove joint

More refined techniques aim to weld the fibre ends together using either a gas flame or an electric arc for the purpose. The fibres are clamped into a jointing machine where they can be viewed either through an optical magnifying system or on a small visual-display screen. Mechanical servo-adjustors allow for the lateral movement of the fibres in 2 planes to provide the alignment. The control of the welding flame or arc is automatically controlled both for temperature and duration since these are critical factors in achieving a satisfactory weld. Joints made by this technique have very low losses, typically 0.5 dB or less. It is virtually certain that this jointing technique, known as *fusion splicing*, will become the general standard in BT since it is essential for monomode fibre jointing.

Fig. 9 shows fusion splicing taking place in the field.

Connectors

The need for plugs and sockets for optical-fibre systems presents severe design problems if losses are to be kept to acceptable levels.

Various techniques have been developed based on the ferrule system, the lens system and the triple or quadruple ball system. The lens system offers, in principle, the lowest loss, but imposes very accurate fibre alignment requirements. The ferrule technique in which the fibres are aligned in a

FIG. 9—Fusion splicing on one of the proprietary 8 Mbit/s routes in London

(Photograph courtesy of Standard Telephones and Cables plc)

small (2 mm) diameter ferrule and the triple-ball technique using 3 small ball bearings to form a triangle to align the fibres, both offer practical arrangements at a relatively low loss, say, 1 dB. A plastic plug and socket in which the fibre is moulded into position has also been demonstrated successfully.

Light Sources

Fig. 4 indicated the operating wavelength region currently used on optical fibres. It follows, therefore, that the wavelength of an optical light source for an optical-fibre system should be in this same region. The other important requirements are that the light source should have high optical power density, minimal beam divergence, high spectral purity and be physically small. The 2 broad categories of semiconductor light sources that are commonly used are LEDs and lasers.

Light-Emitting Diodes

LEDs currently used for optical-fibre communications are based on the semiconductor gallium arsenide (GaAs) which differs from the more common materials germanium and silicon in that carrier recombination occurs efficiently by the emission of optical radiation at infra-red wavelengths rather than by the production of heat.

In its simplest form, the GaAs LED is no more than a forward-biased p n junction diode. Various structures have been developed aimed at achieving a high radiance. The most recent developments have been edge-emitting LEDs which are based on a double-heterostructure construction with the optical output taken from one of the side faces in line with the stripe. Edge-emitting LEDs (Fig. 10) have the advantage of having a high optical output power compared with other types without the disadvantages of the close current control required by semiconductor lasers. Typical LEDs have a wide spectral spread; that is, they radiate a range of wavelengths. The light output is obtained by connecting a fibre directly to the light-output region, or by using a small lens to focus the light into the fibre core.

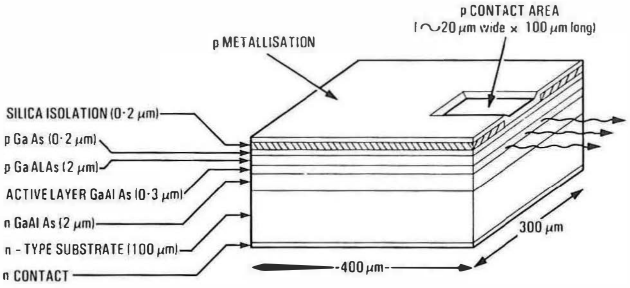


FIG. 10—Edge-emitting LED

Lasers

Semiconductor lasers are used in optical-fibre systems because they have the advantage of being extremely small and have reasonable power requirements. Fig. 11(*a*) shows the construction of a narrow-stripe double-heterostructure laser. An optical cavity is formed by making opposite ends of the device flat and parallel to each other and perpendicular to the active region. At low drive currents the laser behaves like an LED, its emitted optical radiation being spontaneous in the form of photons, which are quanta of light energy. At certain critical drive currents, known as the *threshold current*, a round trip gain of unity is achieved and laser action occurs. Above the threshold current, electrical energy is efficiently converted into optical radiation, some of which is emitted from the end faces of the laser. Fig. 11(*b*) shows a typical output-power/drive-current characteristic. Points worthy of note are that the threshold current is sensitive to temperature and that above threshold a comparatively small increase in drive current can cause considerable increase in optical output. Consequently, when incorporated into systems, the threshold current and signal modulation current have to be closely controlled, usually by means of a feedback circuit, to prevent damage to the laser.

Lasers can be designed such that the area emitting the optical radiation matches the optical fibre to which it is to be connected by altering the stripe width. With properly designed laser structures, the spectral spread can be reduced to 1–2 nm, a factor of more than 10 times narrower than a high radiance LED. Table 1 shows the typical optical power levels coupled into multimode fibres from GaAs based devices. Lasers are likely to be favoured for high-capacity systems using long regenerator spacings. Important factors are reliability and long life, and much work continues into understanding and controlling failure mechanisms.

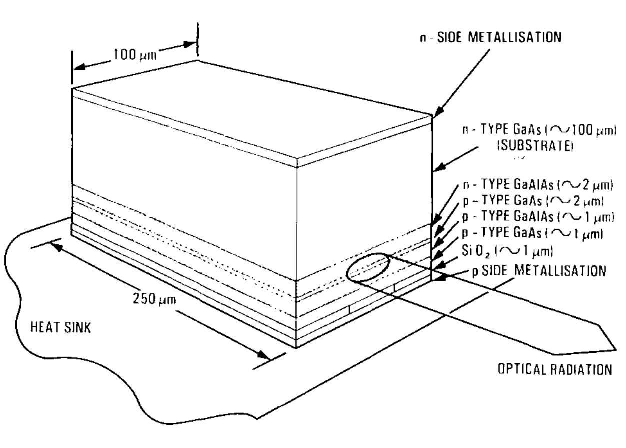
Optical Detectors

An optical detector is required at the receive end of the fibre to detect the modulated light pulses and to convert them

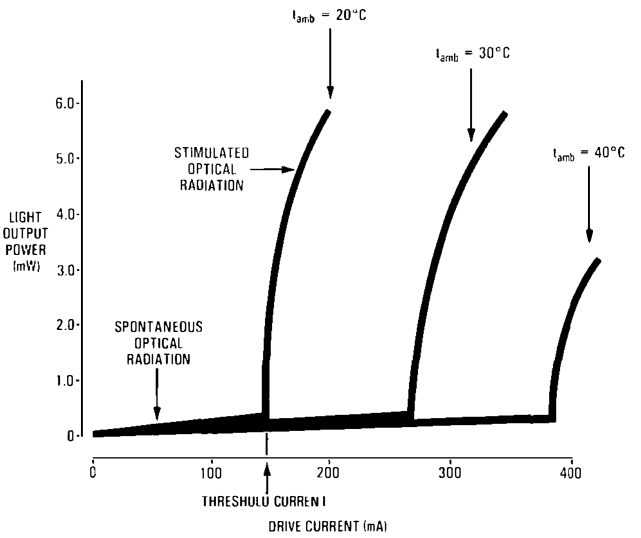
TABLE 1

Typical Optical Power Levels Coupled into a Multimode Fibre

Device	Coupled Power Level
Laser	1·0–4·0 mW
LED	50–150 μW
Edge-emitting LED	250 μW–1·0 mW



(*a*) Narrow-stripe double-heterostructure laser



(*b*) Typical optical-power/drive-current characteristics

FIG. 11—Semiconductor laser

back to electrical energy. The most suitable devices are semiconductor photodiodes on the grounds of cost, reliability and size. They must also have high optical sensitivity, high speed of response and low noise. The 2 main types are avalanche photodiodes (APDs) and PIN photodiodes.

Avalanche Photodiodes

A photodiode in its simplest form is a p n junction on which the light is usually incident to the junction plane. The absorption of light in the vicinity of the junction produces electron-hole pairs which can come under the action of the electric field in that region. When a reverse bias voltage applied to a p n junction is close to the breakdown voltage, the carriers traversing the very-high electric field region at the junction gain sufficient energy to create new electron-hole pairs when they interact with the crystal lattice. This avalanche multiplication can be detected as the electrical output. The quantum efficiency of APDs can be significantly increased by extending the depletion region of the diode giving rise to a device known as a *reach-through APD.* APDs enhance overall system performance at 850 nm, but suffer from the disadvantage that they require high reverse-bias voltages; typically, 300–400 V. Also, the breakdown voltage increases with temperature and this causes a decrease in the quantum efficiency. APDs have been used extensively in early work, but are now being overtaken by PINFET hybrid modules, which are preferred at 1300 nm.

PIN Photodiodes

The absorption of light in the vicinity of a p n junction produces electron-hole pairs which then drift under the action of the electric field in opposite directions across the depletion region thereby causing a current flow through a load resistance in an external circuit. Reverse-bias voltages of typically 20 V are required. The performance of a simple p n junction photodiode can be significantly improved by incorporating a high-resistance intrinsic layer which is sandwiched between the p n regions. This creates a basic PIN photodiode. The thickness of the intrinsic layer can be made much greater than the depletion region of the basic p n junction with consequent improvement in quantum efficiency. Because PIN photodiodes are generally less expensive than APDs and because they require much lower operating voltages, they are clearly very attractive. Sensitivity can be improved by combining the PIN photodiode chip with a field-effect transistor (FET) chip on the same substrate thereby minimising stray capacitancies and increasing the sensitivity of the PINFET combination to within 2–3 dB of that of the APD. The PINFET combination also has advantages of being more sensitive at longer wavelengths than other devices.

As for optical sources, ruggedness, reliability and efficiency are prime considerations and are subject to continuing research and development work.

MAIN AND JUNCTION NETWORK APPLICATIONS

Proprietary Systems

After the success of the experimental routes installed in 1977, BT decided that it was essential to maintain the momentum so created and order a number of operational systems for the network. Discussion between BT and Industry highlighted the difficulties in attempting to specify separately cables and equipment on a standard basis at that early stage in the evolution of this new technology. Accordingly, BT decided to accept proprietary designs of fibre cable and optical line systems, thereby allowing maximum innovative freedom to individual designers. Further, in order to allow optimisation between fibre and equipment performance, it was decided to purchase the schemes on a turnkey basis. Contracts were placed with a prime equipment supplier who in turn selected a cable manufacturer to supply the optical-fibre cable. In this way, the prime supplier, in conjunction with his sub-contractor, could have freedom to optimise the route design. BT limited its specification to the end-to-end performance targets and safety considerations.

Invitations to tender were sent out in 1978 and in early-1979 contracts were awarded for 15 routes operating at 8, 34 and 140 Mbit/s. The 15 routes were deliberately chosen to provide a variety of conditions under which cables and systems must operate. The aim of the exercise was to ensure that both Industry and BT would gain experience of production, installation, commissioning and maintenance of operational systems. Cable was to be laid underground in duct and deep-level tunnels, under water and overhead strung on catenary wires between poles in rural locations. It was decided that each cable should contain 8 fibres of the graded-index variety. Repeater spacings and equipment design were left entirely to the supplier. Overall the order totalled some 3600 km of fibre.

The first route to be completed was the Brownhills–Walsall 8 Mbit/s scheme in September 1980, by which time it was clear that there was sufficient confidence in the programme to justify further orders of a proprietary turnkey nature.

In 1981, BT placed orders for a further 65 routes requiring nearly 12 000 km of fibre. This second order was notable in that it included the first monomode 140 Mbit/s route to be ordered. This was to operate between Luton and Milton

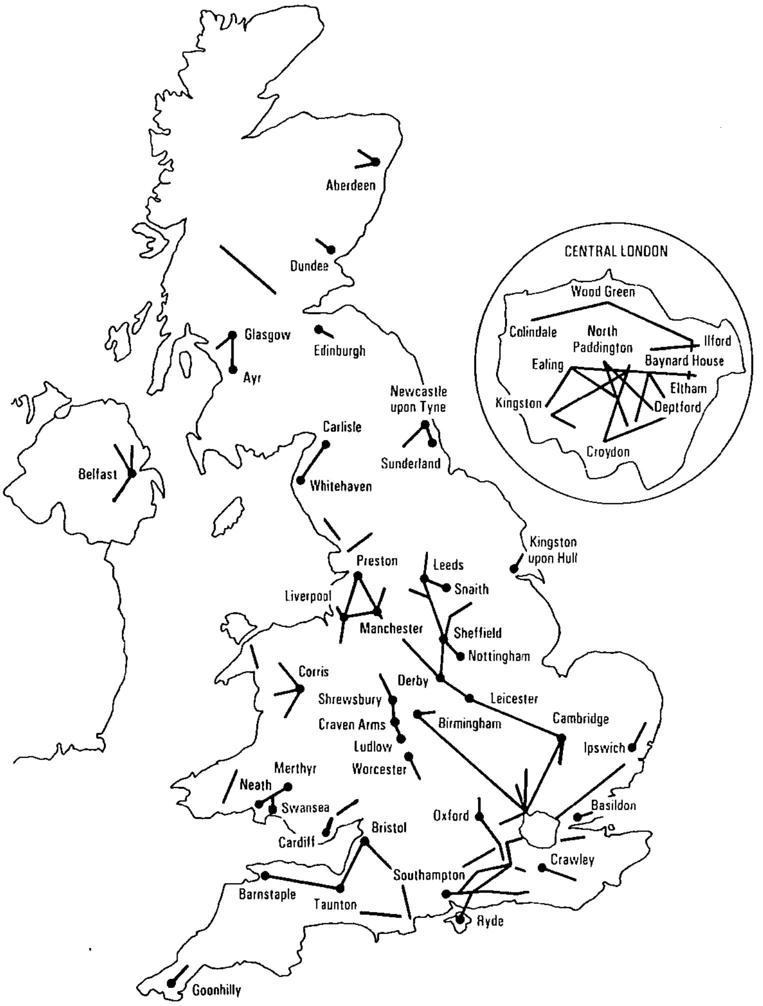


FIG. 12—Proprietary optical-fibre network

TABLE 2
Summary of Proprietary Optical-Fibre Systems

Number of Routes	115
Systems	
140 Mbit/s	155
34 Mbit/s	140
8 Mbit/s	82
Total	377
Cable	
Sheath-km	3 250
Fibre-km	26 000

Keynes, a distance of some 27 km, without intermediate regenerators. It also included the longest optical-fibre route to date, a distance of 204 km between London and Birmingham.

A third proprietary order for 35 routes was placed in 1982. This order included a second monomode 140 Mbit/s route to operate between Preston and Liverpool and a submarine monomode system between Portsmouth and Ryde.

Overall, the 3 packages of proprietary systems achieved their objective of giving wide experience of production, installation and commissioning of routes. Additionally, they gave a continuous programme for industry, stretching from 1980 to 1985. Tables 2 and 3 and Fig. 12 summarise the proprietary orders.

External Plant Considerations

The proprietary orders gave the opportunity to gain experience in cabling operations with optical fibres and the utilisation of external plant.

Provided the cable designs have an adequate strength-to-weight ratio, experience has shown that optical-fibre cables may be handled in the same manner as for any small-diameter cable (Figs. 13 and 14).

The small diameter of the cable means that, in principle, much greater use can be made of the existing duct capacity. Experience has shown, however, that care is necessary in exploiting this advantage. The proprietary orders required optical-fibre cable to be drawn into ducts already containing one or more existing cables in nearly 45% of cases. Small cables can easily become wedged in such circumstances. Even when an empty duct is available, there is a danger that 2 or more small-diameter cables can become tangled. Based on this experience, some provisional planning rules have been formed and development work is continuing into ways of better exploitation of the existing duct network.

Economic Considerations

The proprietary orders gave manufacturers the opportunity of assessing the true costs of this new technology. The cost of optical fibre is quantity related—the wider the application the lower the likely projected future cost. Based on these

TABLE 3
Some Technical Details of the Proprietary Optical-Fibre Systems

	8 Mbit/s	34 Mbit/s	140 Mbit/s	140 Mbit/s Monomode
Operational Wavelength	850 or 1300 nm	850 or 1300 nm	850 or 1300 nm	1300 nm
Opto-electronic devices				
Transmit	LED or laser	LED or laser	LED or laser	laser
Receive	APD or PINFET	APD or PINFET	APD or PINFET	PINFET
Typical Maximum System Length	24 or 280 km	280 km	280 km	—
Maximum Repeater Spacing	25 km	20 km	10 km	30 km
Power Feed Station Spacing	up to 60 km	up to 50 km	up to 32 km	—
Equipment Practice	TEPIE	TEPIE	TEPIE	TEPIE
Cable				
Number of Fibres	4, 6 or 8	8	8	8
Fibre Type	Graded-Index	Graded-Index	Graded-Index	Monomode Step-Index
Fibre Dimensions	50/125 μm	50/125 μm	50/125 μm	9/125 μm
Optical Attenuation	below 8 dB/km	below 8 dB/km	below 3·5 dB/km	below 1 dB/km

predictions and the known costs for the proprietary orders, BT has concluded that the provision of a new optical-fibre cable equipped with optical line systems is more economic than the provision of a new coaxial cable and associated line systems. Fig. 15 illustrates this point.

FIG. 13—Landing a subaqueous section of optical-fibre cable

(Photograph courtesy of North-western Evening Mail)

FIG. 14—Installation of overhead optical-fibre cable in Wales

The junction network is typified by relatively short routes of small capacity. For the digital era, the planned method of provision is 2 Mbit/s line systems on either audio cables or specially provided transverse-screen cables. These latter cables are a development from simple local-line-cable technology and result in a very inexpensive cable. Against this, a 2 Mbit/s optical line system cannot be justified on economic grounds. Higher capacity systems, for example, 8 Mbit/s, require additional multiplex equipment and again, on present predictions, cannot be justified economically. There is a case, however, for optical-fibre systems working at 34 Mbit/s on the higher-capacity longer routes in the junction network (see Fig. 16).

Standardised Systems

The continued provision of proprietary optical-fibre systems can present long-term difficulties in network planning and maintenance because of the many different varieties of equipment and cable. Because of these difficulties and in view of the experience gained, BT, in collaboration with Industry, embarked in 1981 on a programme of evolving

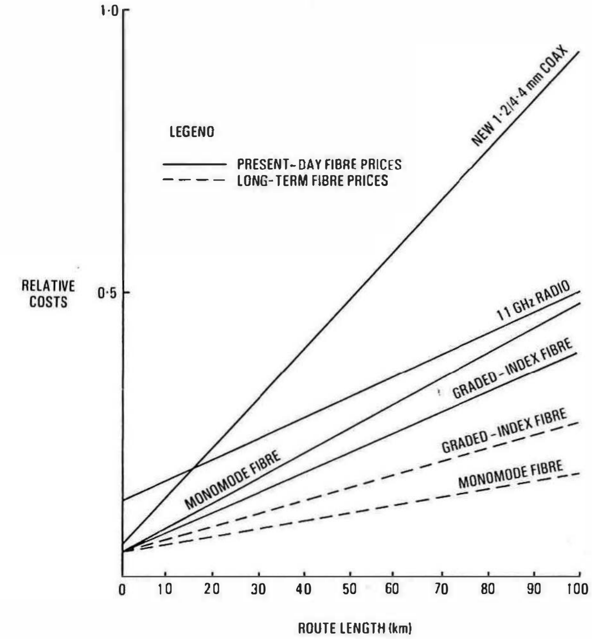


FIG. 15—Cost comparisons—main network

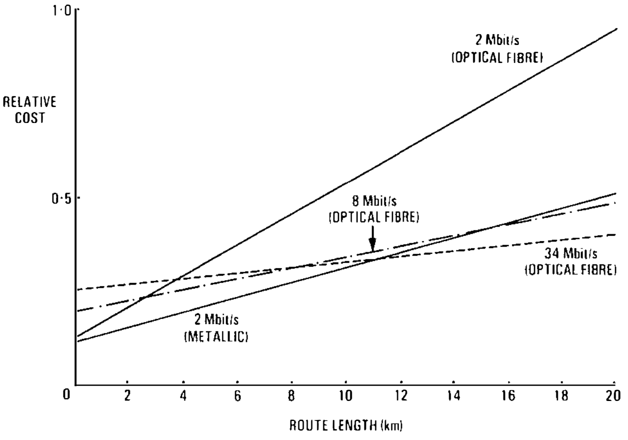


FIG. 16—Cost comparisons—junction network

standard designs of systems for the following 3 broad classifications:

(*a*) multimode (graded-index) fibre at 34 Mbit/s,
(*b*) multimode (graded-index) fibre at 140 Mbit/s, and
(*c*) monomode (step-index) fibre at 140 Mbit/s.

The foremost objective was that any design of system within a classification could be used on any manufacturer's cable intended for that application. The second objective was a high degree of design compatibility leading to the performance and facilities being the same, although the detailed design from each manufacturer was not necessarily identical.

The most significant design objectives for each type of system are set out in Table 4.

It will be seen that for main-network applications there are considerable advantages in the monomode design which can have regenerators spaced at 30 km. The present coaxial cable network is planned on there being a surface building with secure power at intervals not exceeding 30 km. Consequently, a system design which can accept regenerator spacings at this distance avoids the use of power feeding over the cable and does not require regenerators in underground housings. The consequent simplification in design and cost reduction are of considerable importance with the further advantage that it is no longer necessary to provide copper pairs in the cable for power feeding to intermediate regenerators.

TABLE 4
Standard System Design Objectives

Type	Network Application	Regenerator Spacing	Power Feeding	Remarks
34 Mbit/s	Junction	10–15 km (Terminal stations only)	None	
140 Mbit/s (Multi-mode)	Main	10 km	± 100 V	Large number of metallic conductors
140 Mbit/s (Mono-mode)	Main	30 km (Surface stations only)	None	Small number of metallic conductors

Provided that the system supervisory needs are carried on the optical path, the only pairs that need to be incorporated in the cable are those required for a jointer's speaker circuit needed for cable installation and maintenance.

Initial orders for the standardised systems were placed in 1982.

LOCAL NETWORK APPLICATIONS

For the purpose of supplying the basic connection between telephone and local exchange there are, at the present time, neither technical nor economic advantages in using optical fibres in preference to metallic conductors.

Local communications, however, are poised to break into the "information technology" era. A report to the UK Government in early-1982 by the Information Technology Advisory Panel (ITAP) proposed the establishment of a wideband local communications network capable of providing a number of facilities, notably television channels. The Hunt report[6] published in October 1982 recommended that cable television be established in the UK. Other information facilities could, of course, be provided such as Prestel, remote banking facilities, remote meter reading etc. There is much activity at the present time in studying the likely format of such networks, the types of services which could be offered and the transmission media to be used. Another article in this issue of the *Journal* deals with this subject[7].

In 1982, BT launched an experimental star-network configuration using optical fibres to provide a sample of these wideband facilities to a selection of houses in Milton Keynes. Although modest in scale (serving only 18 customers) it nevertheless provides valuable experience. The facilities offered are the normal 'off air' television channels together with a pay-television service, Prestel and stereo radio broadcasts. The signals are transmitted via optical fibres to an intermediate distribution point housing a microprocessor controlled wideband switch which is operated under the customer's control.

A number of other trial local-network installations will be established and clearly the use of optical fibres in the local network will be an area of major importance over the coming years. The size of the local network is such that if optical fibres found wide-spread application, the demand would totally exceed the requirement of the main and junction network.

UNDERSEA APPLICATIONS

The rapid development of optical-fibre technology for land communications has naturally stimulated interest in its application for undersea communications. Submerged optical systems are likely to use monomode fibre at wavelengths of 1·3 and 1·55 μm. Transmission rates of 140 and 280 Mbit/s are probable in the first applications.

Cable designs for submerged systems are now being investigated in several countries. It will be necessary to protect the fibres from stress, and deep water cables are likely to be about 25 mm (1 in) in diameter. It will be possible to include several pairs of fibres in a cable so that the ultimate system capacities could be very large. Repeater spacings at 40–60 km will be substantially greater than those achievable with coaxial submarine cables. It is anticipated that commercial optical-fibre systems will be available by the mid-1980s for short- and medium-haul undersea applications, and long-haul systems suitable for transatlantic operation are expected by the late-1980s although some submarine installations were included in the proprietary schemes as indicated earlier.

In 1980, BT in collaboration with Standard Telephones and Cables plc, successfully installed an experimental submerged optical system in Loch Fyne in Scotland. A loop of cable was laid at an average depth of about 100 m. The cable has 6 optical fibres: 4 multimode graded-index fibres

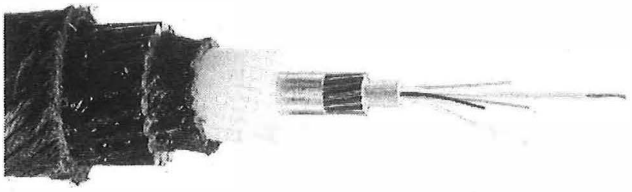


FIG. 17—Loch Fyne optical-fibre cable

for operation at 850 nm and 2 monomode fibres for longer wavelength operation (see Fig. 17). The basic design was intended for use at depths up to 8 km. Active repeaters were inserted into the cable in May 1980, operating at 140 Mbit/s at 850 nm.

The use of optical-fibre systems in submarine conditions imposes onerous reliability requirements. A specified service life of 25 years with a reliability such that a system failure rate of less than 1 failure in 10 years is necessary. Nevertheless, there is every reason for optimism that these requirements will be met.

FUTURE POSSIBILITIES

Optical-fibre technology is still in the early stages of its evolution and undoubtedly there will be many new paths opening up as a result of the intensive worldwide research and development activity.

As already indicated, early optical-fibre systems designs operated at 850 nm because optical components were easier to design at these shorter wavelengths. The rapid development of 1300 nm devices to gain the advantage of lower fibre attenuation will undoubtedly lead in due course to the availability of components at 1500 nm—the next window of even lower fibre attenuation. For the longer term, research is already underway for new materials to produce devices at much longer wavelengths in the region 3000–6000 nm where fibre losses fall to around 0·01 dB/km and repeater spacings of 500 km are theoretically possible.

System design is likely to be concerned with reduction of costs to make optical-fibre systems more attractive in junction and local-network applications and, for the main network, enhancement of capacity on a single fibre. This may take the form of either wavelength-division multiplexing or time-division multiplexing.

There are 2 categories of wavelength-division multiplexing. In the first, more than one of the available windows in the fibre-attenuation curve are utilized. Although this increases the optical-fibre transmission capability in terms of throughput, it has the disadvantage that each particular window in a multi-window fibre does not have as good a performance as the corresponding window in a fibre optimised for single-wavelength operation. Additionally, the use of the fibre is restricted by the characteristics of the worst performance window.

In the second category only one window is used, but within that window more than one optical carrier is transmitted. This process requires the use of very narrow-band optical sources and very-selective filters for extracting the different wavelengths of the multiplexed carriers.

The second technique is digital multiplexing. An extension of this well established process up to very-high bit-rates, in the vicinity of 1 Gbit/s, may prove more economic than endeavouring to exploit multiple use of the optical spectrum especially in the case of monomode fibre.

The fibres themselves will be produced by ever-improving manufacturing techniques.

Optical-fibre technology has come a very long way since the mid-1960s, but it is doubtful if more than a small step has been taken along the path of opportunities it has to offer.

CONCLUSIONS

Experience of optical-fibre systems to date has led to a number of conclusions regarding their long-term viability in the network. For the main part of the network, there can be little doubt that these new systems will yield a cheaper and more reliable means of providing inter-city circuits in the digital era. This also holds true for submerged systems particularly having regard to the approach of limitations on circuit capacity caused by the physical constraints of wider bandwidth metallic cable systems.

The junction scene is, however, still clouded by costs. At present, only a few routes have a configuration which could benefit from optical-fibre systems and a considerable reduction in costs must be realised before such systems find a place in this sector. Hopefully, the placing of orders for longer-route systems will be instrumental in reducing prices, particularly basic fibre costs, and this should lead to a change in their economics for junction use.

In the local network, the position is compounded by political as well as economic considerations. Technically, optical fibres have a lot to offer in terms of wideband system performance, and this may yet prove to be the largest area of application of optical fibres.

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Transverse-Screen Cables

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UDC 621.315.2: 621.394.4: 681.327.8

The increasing use of digital transmission in British Telecom's junction network has highlighted limitations in the suitability of audio quad cable for conversion to digital working. This article describes a range of low-cost metallic-pair cables designed to work at 2 Mbit/s and suitable for applications in the junction network and for direct connection to customers' premises.

INTRODUCTION

For many years, digital transmission has been provided in British Telecom's (BT's) transmission network to carry multiplexed pulse-code modulation (PCM) systems. Until recently, the provision of these systems was justified only when they were cheaper than the appropriate equivalent analogue plant. However, the advent of System X exchanges and the availability of an increasing range of customers' terminal equipment with digital interfaces have transformed the economics and made digital transmission an essential requirement. The resulting explosive growth in the provision of 2 Mbit/s digital transmission systems has shown up limitations in the ability to exploit existing cables and has led to the consideration of new cable designs[1]. This article describes a metallic-pair type cable specifically designed for digital transmission, its principal use being for 2 Mbit/s circuits in the junction network and for circuits to customers' premises. A main feature of the cable is an intrinsic low-cost design which allows quick installation using readily available staff skills.

IMPACT OF SYSTEM X ON JUNCTION PLANT PROVISION

Several years ago, it was decided, as a result of the decision to introduce digital switching exchanges, that all new plant planned for junction circuit growth should use digital transmission. In addition, it is the aim that all existing junction circuits at present routed on analogue plant will be changed over to digital transmission systems by the year 2000.

To meet the junction growth and conversion requirements, together with other needs, about ten-thousand 2 Mbit/s digital line sections (DLSs) per year must be provided. When contrasted with about eighteen thousand 1·5 Mbit/s DLSs provided for 24-channel PCM systems over the past 12 years, this indicates the challenge ahead for planning and plant installation teams. It also highlights the limitations of existing audio quad cables which, in many cases, cannot economically support the required number of DLSs.

CONVERTING EXISTING CABLES TO DIGITAL TRANSMISSION

From the outset, PCM was regarded as a means of enhancing the capacity of existing audio cables. Existing cables, of course, represent a very large capital investment and there are obvious attractions to substituting electronic regenerators for loading coils and providing line terminal equipment to produce a DLS.

Although the original planning rules allowed 1·5 Mbit/s DLS to be provided with almost no trouble, the change to the 2 Mbit/s CCITT* standard system caused difficulties with the existing audio quad cables, which have proved incapable of supporting the expected number of systems. After an extensive review of cable characteristics, new planning rules were produced that allowed for a trade-off between cable fill and regenerator spacing. The resulting changes in costs, therefore, altered the economic relationships between converting audio cables and installing new cables. These changes did not rule out the use of existing cables, but emphasised the need for careful cost comparison of the alternatives which, in turn, led to detailed consideration of the type of cable to be used for further provision.

NEW CABLES

Various types of cable optimised for digital transmission are possible. Optical-fibre cables are perhaps the most obvious contender. Although viable at 34 Mbit/s and above, they do not yet prove economically attractive for the low circuit capacity routes so frequently encountered in BT's junction network. The requirements for metallic-pair digital transmission cables were therefore considered, with the emphasis on pair-type construction rather than the more traditional quad-type which has its origins in the particular requirements of 4-wire audio transmission.

NETWORK REQUIREMENTS

Cable requirements are dictated by network needs. BT's junction network consists of about 1 200 000 circuits serving about 6200 local exchanges. Some of these inter-exchange links can be up to 50 km long and others have capacities of 1000 circuits and more.

Junction network circuits are predominantly short in length (see Fig. 1). However, this can be misleading when translated into cable requirements because short high-density routes account for many circuits, but only a small proportion of cable route length. For example, the 58% of circuits that are 10 km long or less represent only about 20% of cable route length. The cable network, therefore, mainly consists of thin routes, and about 75% of total route length is accounted for by routes having 240 circuits or less.

The principal network requirement, therefore, is for a small cable with a digital capacity of around 240 circuits, and a larger cable of about 1000 circuit capacity for applications that had previously been met by the largest audio quad cable size of 1040 pairs.

CABLE CHARACTERISTICS

In designing a cable to meet the operational requirements outlined above, there are a number of characteristics that must be considered.

Regenerator Power Feeding

Before considering the high-frequency (HF) characteristics, it is necessary to establish the power-feeding requirements, as these influence conductor size. As Fig. 1 shows, the UK junction network consists of many short routes, but with a

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* CCITT—International Telegraph and Telephone Consultative Committee

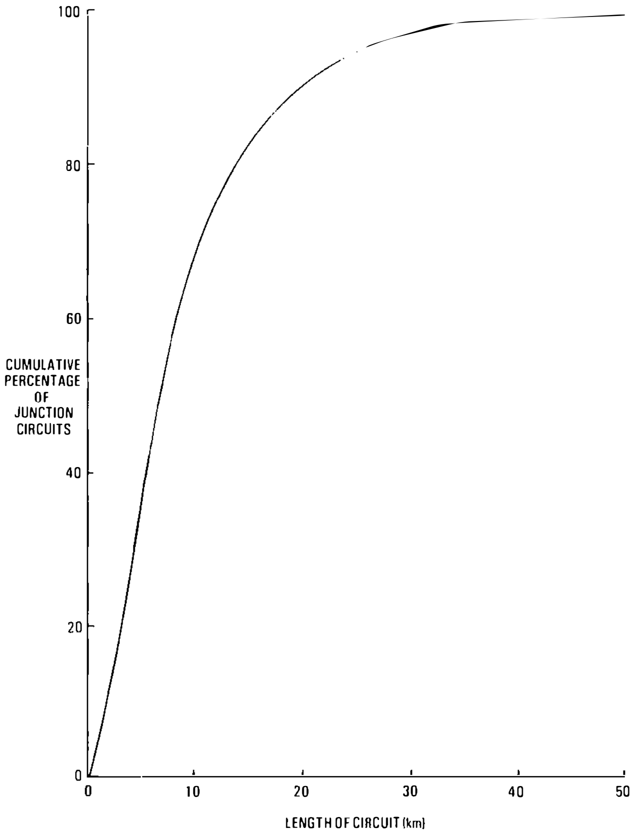

Fig. 1—Cumulative percentage of junction circuits to a particular length

sizeable tail on the distribution extending to 50 km and more. Nevertheless, some 96% of circuits are 30 km long or less. Thus, there is a requirement to power feed regenerators over distances of about 15 km from each end of the cable. Table 1 shows the approximate power feeding distances which can be achieved using the present UK design of regenerators with a range of conductor sizes.

It can be seen from Table 1 that the 0·6 mm diameter conductor is the most suitable. The smaller diameter conductors cater for too short a range, whereas the larger ones are more expensive and unnecessary for the task.

Attenuation

The HF transmission attenuation of a cable is determined by the HF resistance of the conductor, the ratio of the wire/conductor diameters, and the dielectric material of the insulation. The HF resistance provides the most important contribution, but at high frequencies a change in conductor diameter has a proportionally less effect than at low frequencies. Therefore, in seeking an optimum return on material costs, a small conductor diameter with a thick insulation is the most favourable. However, the ultimate choice of 0·6 mm conductors was principally dictated by the power-feeding requirements, leaving the insulation material and its dimensions as the variables to be studied.

TABLE 1
Approximate Maximum Route Length for a Range of Diameters of Copper Conductor

Conductor Diameter (mm)	0·4	0·5	0·6	0·7	0·8	0·9
Maximum Distance with Power Feeding from Both Ends (km)	19	24	30	32	34	37

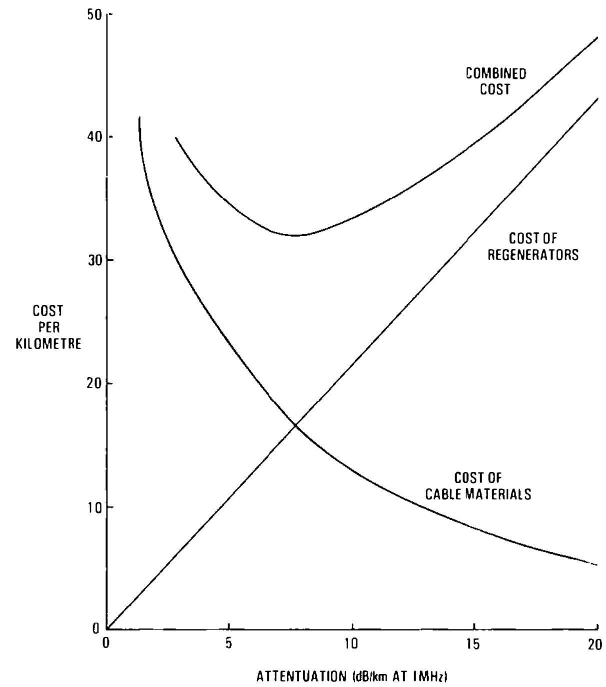

Fig. 2—Effect of attenuation on cable and regenerator costs

In the design of the cable, the amount of HF attenuation that is acceptable is governed by a compromise between cable costs and regenerator costs. Although the material costs of a cable are roughly proportional to its cross-sectional area, the attenuation of the cable is inversely proportional to its diameter. Thus, as the attenuation is reduced, the cable material costs are increased by an inverse law, but the number of regenerators required, hence the regenerator costs, decrease linearly. One study[2], the results of which are shown in Fig. 2, suggests that an attenuation of about 8 dB/km is optimum. However, when assumptions about installation costs and duct occupancy are included, the combined cost curve becomes much shallower and a good solution falls anywhere in the range 11–16 dB/km.

Near-End Crosstalk

Near-end crosstalk (NEXT) can be controlled by placing a diametric screen made of aluminium foil between the 2 groups of pairs used for carrying opposite directions of transmission. At 2 Mbit/s, a simple screen with a minimum wraparound at the edges is adequate, although for higher bit-rates much greater attention must be given to the screening of the 2 halves. It was decided at the outset, however, to restrict the main use of the cable to 2 Mbit/s systems and let optical fibres deal with the demand for 8 Mbit/s capacity and upwards. This had the main advantage of keeping the cable design simple, and hence the costs low.

Far-End Crosstalk

Far-end crosstalk (FEXT) is of concern within the group of pairs forming one direction of transmission. FEXT can be controlled by introducing a variety of twisting lengths to the pairs which make up the group. Additionally, the twisting of individual pairs can be varied along a length. In practice, the number of different twist-lengths on the same side of the screen varies from manufacturer to manufacturer. The number of twist-lengths used is also related to the type of manufacturing machinery available and hence to cost as well as performance. The optimum method of meeting the performance specification at minimum cost is therefore a matter of judgement by each manufacturer.

The presence of the screen, principally to provide adequate NEXT, also has an effect on attenuation and to a lesser extent on FEXT. Pairs in units in the crook of the screen wraparound have a noticeably higher attenuation (of the order of 3% higher). Experience with other cables suggests that FEXT performance is also degraded by the presence of extra metal elements such as moisture barriers etc. There is only limited data available on different constructions of transverse-screen cables, but prudence suggests that the screen size should be limited to the minimum necessary to secure the required 2 Mbit/s NEXT performance.

THE CHOSEN DESIGN

The characteristics outlined above, namely DC resistance, attenuation, NEXT and FEXT, are all interactive. For instance, for each 1 dB extra attenuation, the NEXT signal-to-noise (S/N) ratio is worsened by 1 dB. Similarly, the FEXT S/N ratio worsens by about 4·5 dB for each doubling of length. Some of the other interactions, especially with cost, have already been highlighted.

The ideal is to have a cable in which the variable factors are optimised to peak at a regenerator spacing that gives the lowest installed system cost. Inevitably, practical considerations such as compatibility with existing manufacturing and installation techniques influence the solution, but these are consistent with low overall cost.

The design chosen for evaluation and subsequently adopted (Fig. 3) had pairs made up from standard 0·6 mm diameter copper conductors, which meet the required power-feeding criteria. The conductors were insulated with cellular-polyethylene to an overall diameter of 1·35 mm. This gives a typical attenuation at 1 MHz of 14 dB/km, but with a maximum in excess of 15 dB/km.

The pairs on each side of the transverse screen are constructed from 10-pair units, with 5-pair sub-units permitted. A cable with pairs and units having these parameters, but without the transverse screen, has been introduced recently for use in the local distribution network and was designed with the possibility of one-way digital transmission in mind. As local distribution cable is produced in large quantities, there were clear cost advantages to transverse-screen cables in rationalising designs.

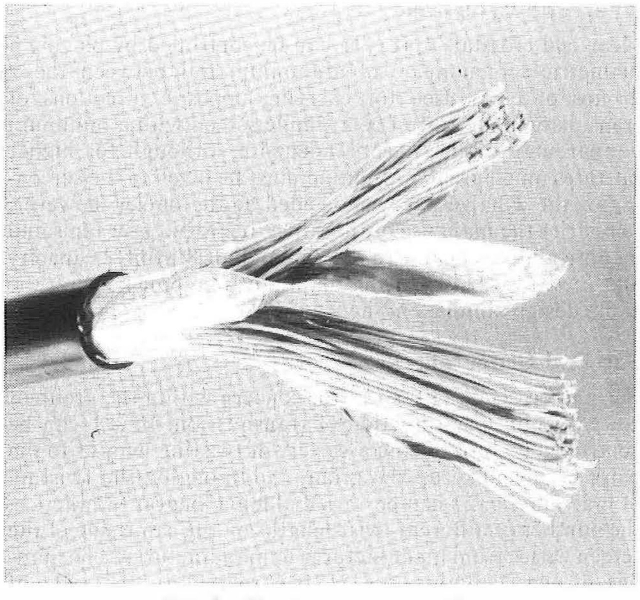

FIG. 3—Transverse-screen cable

Present-day regenerators are capable of dealing with section losses of 37 dB at 1 MHz, which represents just under 2·4 km of cable at maximum loss. A simple transverse screen made from aluminium foil of 75 μm minimum thickness and polymer coated on both sides allows the required NEXT S/N ratio at 2·4 km to be easily achieved. The precise configuration and the amount of wraparound varies with cable size and manufacturer. The 2 configurations in use at present are shown in Fig. 4.

The total S/N ratio at the input to a regenerator is, in fact, a combination of NEXT and FEXT disturbing signals. With attenuation and NEXT already determined, the required minimum value of FEXT was calculated. On the evaluation scheme between Basildon and Billericay, various twist-length combinations were tried and all met the FEXT requirements. This experience allowed all the transmission performance figures to be specified for future production in the knowledge that they could be readily achieved.

It was indicated earlier that the principal requirement was for cables with digital circuit capacities of around 240 and 1000 circuits. Assuming 100% digital fills (except for 4 supervisory pairs) and construction from 10-pair units, this gives

(*a*) a 20-pair cable for eight 2 Mbit/s DLS with an equivalent capacity of 240 circuits (8 go pairs plus 2 supervisory pairs on one side of the screen, 8 return pairs plus 2 supervisory pairs on the other).

(*b*) an 80-pair cable for thirty-eight 2 Mbit/s systems with an equivalent capacity of 1140 circuits (38+2 on each side of the screen).

The 80-pair size has the added advantage of corresponding with the capacity of the standard large regenerator housing — the Case Repeater Equipment No. 1A(CRE 1A). In fact the capacity of the CRE 1A was previously considered to be 36 line systems, but it has proved possible to fit in 38. Both these sizes of cable were specified together with 40-pairs and 60-pairs to allow for spurs and tapering cable schemes. Experience has since shown that it is uneconomic to stock the 60-pair size because of low demand.

The main route cable is petroleum-jelly filled and polyethylene sheathed. In addition, an unfilled cable with a moisture barrier has been introduced for exchange terminations and regenerator-housing terminations. This cable has also proved useful in digital conversion work on existing pressurised quad cables for applications such as by-pass cables at loading points[1].

More recently a polyvinyl chloride (PVC) sheathed version of the unfilled moisture-barriered terminating cable has been introduced for use in buildings. The fire-hazard restrictions and costs of routeing polyethylene sheathed cables are thus obviated and the PVC sheath cable allows the cable termination block to be located much nearer to, and sometimes actually on, the rack containing the line terminating equipment.

The 20-pair size has been produced in aerial versions both in a self-supporting figure-of-eight construction embodying

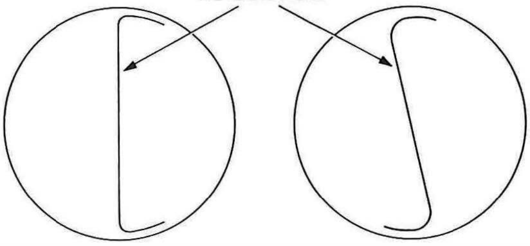

FIG. 4—Screen configuration

a steel suspension wire and in a circular form for lashing to a separate steel suspension wire.

All sizes can be provided in a wire-armoured version for direct burial, although, at the moment, only the 20-pair size has been produced. Investigations continue into a special wire-armoured version suitable for subaqueous applications.

ASSESSMENT AND TYPE APPROVAL

The evaluation of the first scheme between Basildon and Billericay was carried out with the R92A digital crosstalk tester using pair-to-pair and barrage measurements. This tester has been described elsewhere[3,4,5]. Once the cable design concept had been confirmed as satisfactory, the electrical and physical parameters were specified for production. Early production was subjected to rigorous testing, again with the R92A tester. Agreements with manufacturers allowed type approval to be given to each of their designs to avoid the need for costly digital testing in the factory. Performance at 1 MHz was specified to provide a production yardstick (Tables 2 and 3).

TABLE 2
Attenuation (Insertion Loss)

Number of Pairs in Cable	Insertion Loss Measurements (maximum for 99% of all cases)
All sizes	15·5 dB/km

Values of attenuation measured as insertion loss between 120 Ω resistive terminations at a frequency of 1 MHz.

TABLE 3
Crosstalk Attenuation

Crosstalk Test	Number of Pairs in Cable	Minimum Attenuation (dB)	
		($\bar{x} - \sigma$) Note 1	99% of Cases
NEXT across Transverse Screen	20 40 60 80	75 78 80 81	69 69 69 69
FEXT on same half of Transverse Screen	20 40 60 80	61 64 66 67	49 52 54 55

Measurements of crosstalk attenuation made between 120 Ω resistive terminations and at a frequency of 1 MHz

Notes 1: Mean ($\bar{x}$) minus one standard deviation (σ)
2: The figures relate to total production and not specifically to individual cable lengths

Several installed cables have subsequently been tested with the R92A tester to ensure that performance is being maintained in volume production. This performance has been confirmed and the success in achieving a close approach to the optimum design can be seen in Fig. 5. The boundaries of performance are 37 dB insertion loss and 30 dB signal-to-barrage noise measured on the R92A tester. (The latter figure is determined in the laboratory.) The graph shows the worst-case readings from a sample of early production 80-pair cable. The optimum economic/technical performance would appear to be for the total barrage noise (NEXT plus FEXT) to pass through the intersect of the limits, but practical considerations dictate that operation is required on the safe side of them.

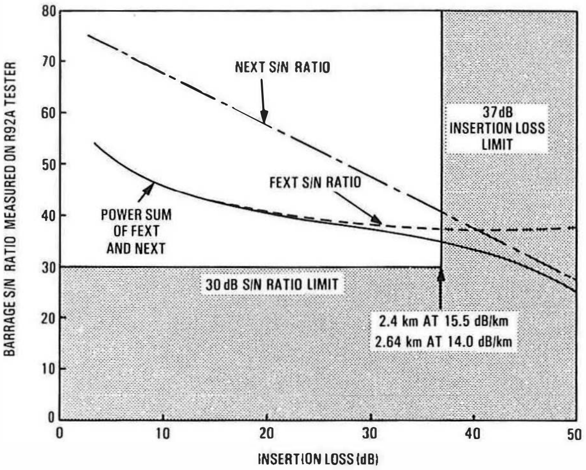

FIG. 5—Performance of transverse-screen cable

REGENERATOR HOUSINGS

At about the same time as the transverse-screen cable was being evaluated, new regenerator housings were being considered for use on existing quad cables. The size requirement of one of these was uprated from 6 systems to 8 systems to correspond to the needs for the 20-pair cable. This regenerator housing, the Case Repeater No.10A, was originally produced with 4 integral quad tail-cables. The latest version, the Case Repeater No.10B now has 2 integral 20-pair transverse-screen tail-cables which allow simple connection to the main transverse-screen cable.

The tail-cable used with the CRE 1A was also re-engineered to use two 80-pair transverse-screen cables to improve crosstalk performance and make jointing straightforward on transverse-screen cable schemes.

REGENERATOR SPACING

While the cable has been designed to support regenerator spacing at up to 2·4 km intervals, in practice, a more conservative maximum spacing of 2 km was adopted for the early installations. This was partly because there was only limited experience of production tolerances, but principally because:

(*a*) planning to the limit implies a need for digital testing and possible rejection of pairs: this is expensive; and

(*b*) some margin in performance was felt to be necessary because of effects such as synchronisation and cumulative jitter that would follow later when a wholly digital network was realised.

The straightforward installation and commissioning of the early schemes shows that this caution was worthwhile. Fig. 5 shows that, even on worst-case values at 2·4 km spacing, there is a margin in hand. Further work on synchronous digital signals shows that an extra margin will indeed be needed with the present line system and terminal equipment, although scramblers can be fitted retrospectively to overcome the problem. For the future, a new line system with code translation from the 2048 kbit/s HDB3 (high density bipolar 3) interface code to a 1536 kBaud 4B3T (4 binary to 3 ternary) line code of the MS43 type will overcome several problems at the same time, namely:

(*a*) the code conversion incorporates scramblers to maintain pattern density, which will also minimise synchronisation and jitter effects;

(*b*) the regenerators will operate at up to 40 dB line loss at 1 MHz;

(*c*) a small improvement in tolerance to FEXT noise will be gained; and (*d*) tolerance to NEXT noise will be considerably improved. This is more important for applications on existing audio cables than on transverse-screen cables.

Taking into account some margin to limit the testing requirements, the likely target is for about 2·5 km regenerator spacing in the future.

The regenerator spacings referred to assume a wholly digital cable, except for the supervisory and speaker pairs. However, one of the attractions of the cable is that it is possible to use the pairs for interim audio use prior to the introduction of digital transmission. In this application, loading-coils are provided at 1·83 km intervals with nominal 0·915 km end-sections. It is usually convenient to site regenerator housings at these distances and substitute loading-coils for regenerators until digital conversion. It is, however, possible to provide in-joint loading at 1·83 km intervals and defer provision of regenerator housings. Where this is done, a considerable out-of-service time for the cable must be accepted during conversion.

INSTALLATION

Transverse-screen cables are simple to install using existing practices and techniques. The main features are detailed below.

(*a*) *Small cable size.* The largest version has only 80 pairs and has an overall diameter of 30 mm. The cables are therefore easily handled, can share a duct bore and there are few pairs to joint and terminate.

(*b*) *Long-length cabling.* Typically lengths of 500 m, and in some cases over 1000 m, can easily be installed using the standard rodding-and-light-cabling (R and LC) equipment. Long lengths of 80-pair cable cannot be accommodated on the R and LC vehicle and it is usually cheaper to install shorter lengths using the R and LC vehicle and provide extra joints rather than employ heavy cabling equipment.

(*c*) *Straight joints.* Two ends of the cable are jointed together in-line. This applies even at regenerator housing locations because the tail cables have been designed with this in mind. Pair integrity is maintained throughout (that is; pair 1 is jointed to pair 1, pair 2 to pair 2 etc.). The only exception is at spur cable take-off points and at some joints to termination cables: in both these cases one main cable may branch into 2 cables. Even when interim audio use is envisaged, straight pair jointing is adequate. Screen continuity is always maintained: the screen is earthed at one end only.

(*d*) *Shrink-down sheath closures.* These permit a first-class seal to be achieved in minimum time.

(*e*) *Limited civil engineering needs.* Joints and regenerator housings are easily accommodated in surface boxes. There is considerable freedom in choosing their location, thus allowing existing structures to be utilised.

(*f*) *Limited testing.* Simple DC and attenuation tests between regenerator housings and from the terminations confirm that the cable has been correctly installed. The design characteristics and conservative planning rules ensure that satisfactory digital transmission will result.

The above features contrast sharply with audio quad cables where:

(*a*) lengths of 167 m are typical and 230 m the usual maximum;

(*b*) cables are often large (72 mm diameter for 1040 pairs) and manholes are required for joints and loading-coils on the larger cables;

(*c*) complex jointing arrangements arose from the need to minimise crosstalk by crossing pairs to reduce capacitance unbalances (balancing);

(*d*) sheath closures employ injection-welding techniques which involve considerable set-up times for the apparatus;

(*e*) testing is needed to balance the cable and digital testing is needed before commissioning 2 Mbit/s DLS; and

(*f*) on completion, the cable has to be pressurised (with compressed air) involving a delay of weeks whilst the pressure equalised.

ECONOMICS OF PROVISION

Several factors influence the planners choice between converting an existing audio quad cable for 2 Mbit/s operation and providing a new transverse-screen cable. A cost comparison confined only to the external provision activities shows that a new cable is the marginally more expensive option. This does not, however, take into account a number of practical considerations.

For instance, with existing quad cables circuits may have to be re-arranged to free the pairs wanted for digital transmission. Also, it may be difficult to get physical access to the cable in large jointing structures. Furthermore, in a large cable, the wanted pairs may be in the centre necessitating a long and complicated jointing process to get access to them. However, existing audio cables do have the advantage where the availability of duct space is a problem. New duct is now so expensive that if a new cable requires anything other than short lengths of new duct to be provided, converting an existing cable is clearly cheaper.

Perhaps the major attraction of transverse-screen cable is the short installation time resulting from the inherent design features and streamlined procedures detailed earlier. The use of a limited number of stores items and readily available manpower skills also allows short planning times. Together these mean that the time taken between deciding to provide digital transmission and commissioning the systems is significantly reduced over any alternative. This fast reaction time is of particular benefit in providing customers' point-to-point services where competitors vie for business.

CONCLUSION

Transverse-screen cables are now widely used to provide 2 Mbit/s transmission in the junction network and for point-to-point customers' circuits. The main feature is their low overall cost which aided by straightforward installation techniques, makes them competitive in cost with converting existing audio cables to digital transmission. Paradoxically, this has led to an increase in cable provision for a transmission system originally designed to exploit existing cables.

Transverse-screen cable attributes set a hard target for optical-fibre systems to meet on short low-circuit-capacity routes, but it can be expected that optical fibres will become competitive in this area within a few years.

ACKNOWLEDGEMENTS

The author would like to thank his colleagues for the work they contributed during the introduction of the new cables.

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Multi-Service Cable-Television Distribution Systems

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Cable-TV systems have been developing over a number of years and can now provide a wide range of tele-information services. This article discusses how these tele-information services might evolve and examines the factors concerned in the choice of network topology required to meet the growing demand for cable-TV distribution systems. As an example, it describes briefly the Fibrevision cable-TV trial at Milton Keynes and goes on to outline a possible integrated services wideband network. This article is based on a paper presented to the Society of Cable Television Engineers.

INTRODUCTION

Coaxial cable tree and branch networks have been widely used as a cheap and efficient means of distributing TV signals. Over a number of years they have been developed, particularly in the USA, to the point where the more sophisticated systems provide quite a wide range of services: pay-per-view, rolling-page viewdata, alarms, voting, and limited data facilities. However, looking towards the future from a general tele-information viewpoint and attempting to perceive how the services that are likely to be needed in the home and the office could be provided, limitations become obvious. Therefore, the following questions must be asked: are there other more suitable network topologies; what services can they offer; how efficiently can they be engineered; and at what cost? These questions have not been addressed in the USA because of the constraints of the Federal Communications Commission, so in seeking answers new ground is being broken. But, in the UK, there are also constraints; namely, customer desire, and the commercial and regulatory environment. Thus, it is essential to explore the field as quickly as possible, and set before government and public the options for a tele-information infrastructure that will best serve the future of the country and create potential for exports.

This article attempts to address these questions and arrive at practical engineering conclusions.

SERVICES TO BE CARRIED

The services to be carried on a cable-TV network can be classified as:

(*a*) *distribution TV* free channels, subscription channels and pay-per-view;

(*b*) *data services*;

(*c*) *videotex services* both alpha-numeric and picture; and

(*d*) *individual video services* including 2-way video and video library access.

Each of these categories is briefly examined to see how best they can be organised and what their demands are on the network.

Distribution TV

A coaxial cable tree network operating to British standards will accommodate about 30 TV channels, which is a modest number by advanced American standards. Demands for channels may well be different in this country—much will depend on how programmers set about their job—but already there are indications of how a substantial number of channels will be used, and it will be surprising if something like 30 channels are not required within a few years. The lion's share of bandwidth will undoubtedly be taken by distribution TV, leaving little room for the other services, which are all of an individual point-to-point nature, unless they can win a share by being superior revenue earners. There is a danger that high tariffs may be forced on individual services by bandwidth scarcity.

In addition, account must be taken of the substantial increase in channel bandwidth demanded by future systems. Direct broadcasting by satellite will form an important input to cable systems, probably amounting to 5 or more channels within a few years. The enhanced transmission standards will require a base bandwidth of 10 to 13 MHz, in comparison to the 8 MHz of the current PAL colour coding transmission system. Beyond that, the move towards high-definition TV with 1000 lines or more is gathering strength and will demand bandwidth of about 30 MHz. There is also a move towards digital TV, with digital studios and digital TV sets already emerging. This, together with BT's programme for the rapid conversion of all main network routes to digital transmission must present a strong case for completing the last link in the chain; namely, local distribution, in digital form, demanding bandwidths of 70 MHz or more. These new systems will severely reduce the number of channels carried on coaxial cable tree networks or, conversely, their introduction will be severely limited.

Data Services

Before considering the data facilities that could be provided over a cable-TV network, account should first be taken of the ubiquitous transmission network that already exists—the telephony copper-pair network. BT provides a range of data services over the local copper-pair network, from alarm services up to 64 kbit/s. The copper-pair network has proved to be a remarkably versatile transmission medium, but its upper limit is likely to be reached with the integrated services digital network (ISDN) which will commence experimental service later this year. This will initially provide 80 kbit/s (64+8+8), but may be later extended to 144 kbit/s (64+64+16), which is the probable CCITT* recommendation. Coaxial cable networks have a much greater bandwidth and, therefore, their natural service seems to be the higher bit-rate services that will be required by business customers. Also, occasional low-usage data services, such as required by the home computer market, might be covered by common usage of a wideband channel.

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* CCITT—International Telegraph and Telephone Consultative Committee

There are a number of systems available that provide data services on cable-TV networks; all use principles that have been developed for local-area networks (LANs) whereby a number of users share a data highway. LANs are conceived as networks connecting together a number of autonomous nodes normally using a bus or ring topology. They must cater for the fact that the independently initiated transfers will occasionally demand more bandwidth than the network has available and also must continue to operate when one or more nodes fail. The data is assembled into packets with a header and a tail, and the flow of packets is controlled by contention or collision-control strategies in the case of busses, and by daisy-chain, token or register strategies in the case of rings. The number of users that can be accommodated is remarkably high for low-usage low-bit-rate customers, but for high-bit-rate high-usage customers, such as those requiring file-to-file transfer facilities at circa 2 Mbit/s, which is likely to be a common future business requirement, the numbers accommodated becomes small.

Videotex Services

The take-up of the BT videotex service, Prestel, by the domestic customer has been poor, but there is a market as demonstrated by the sale of teletext TV sets. This probably reflects the public desire for a service that is perceived to be free, but also reflects the high cost of Prestel sets or adaptors. Videotex is of course an individual interactive customer service and can offer such services as home banking and home shopping, while teletext is a non-interactive broadcast service. One way to tackle the cost problem is to share adaptors at some central point, but this requires that a full standard TV picture is sent from the adaptor to the customer and thus makes a very-high bandwidth demand on the customer's link. It is however a technique that has been successfully demonstrated in the Milton Keynes optical-fibre network.

The future in this field probably lies with picture videotex services, whereby the customer is provided with a good definition picture combined with text information, perhaps using a combination of video disc to provide the picture and volatile computer memory to provide the text. This will make possible attractive services such as home buying from illustrated catalogues, illustrated small advertisements and many other such services. BT has developed a picture videotex system, but at a transmission rate of 1·2 kbit/s over the telephone line it takes about 30 s to build up a one-eighth-screen picture and the customer's equipment is costly. Again, the way forward is the central generation of the picture on shared equipment and the transmission to the customer of a standard picture via a dedicated link. As before, the bandwidth requirement to serve a reasonable number of customers is very high.

Individual Video Services

Whenever the future of telephony is discussed, the video telephone immediately comes to the fore, but experience in the UK and other countries has been an unhappy one. BT has been running a Confravision service between major cities for some years and it continues to be underused. This is probably the result, in the main, of a combination of inconvenience (travel to a city-centre studio) and high cost. Currently, BT is preparing a visual services trial[1] based on the premise that businesses will make much more use of video services if the terminals are in the executive's own office or close by; the equipment is reasonably priced (no special studio required); and the charges for long-distance transmission (at 2 Mbit/s using sophisticated bandwidth reduction equipment) are reasonably modest. Video telephones, slow-scan TV and scribble pads will be used by about 20 companies at 50 locations throughout the UK.

It is the intention of BT to link any integrated services wideband local networks it deploys into the visual services network. The wideband local network will enable video services within its own network to be provided reasonably cheaply and the expensive bandwidth reduction equipment will be used in a shared mode at the head-end when long-distance communication is required. Again, the bandwidth requirements will be very high if there is any substantial take-up of the service.

A second type of individual video service is that of customer access to a video library. Such a facility could offer entertainment, instructional, hobby, sport, pop-music items, etc., which could be viewed in an interactive mode as and when the customer wished. This would offer a fundamental and radical change in the viewing options open to the customer who would no longer be constrained to a stream of predetermined programmes. The required technology is becoming available, notably the optically-scanned video disc. On a marginal cost basis the charges that would need to be made for such a service do not seem unreasonable, being comparable with the cost of hiring a tape from a video-library shop. The bandwidth demands would be high, even for a low initial pick-up, and, if the service proved popular, the bandwidth required would be very great. Thus, it is desirable to have a network that can be easily expanded in capacity.

NETWORK TOPOLOGY

Summarising the foregoing in relationship to coaxial cable tree networks, it appears that the tree network is a low cost and efficient method of distributing multi-channel entertainment TV to present standards and it can be engineered to provide a reasonably large number of low-capacity low-usage data customers and a small number of large-usage data customers. Also, via an interactive signalling and control system, it seems quite well suited to the provision of extremely low-capacity information services such as alarms and voting. However, when looking towards a whole range of future services—high-speed data, videotex, individual video services—a critical bandwidth restriction is perceived. Consideration must be given, therefore, to the network topologies that are available and free from this constraint.

The most immediate answer is the star network, in which each customer has an individual broadband connection back to the head-end. All services are accessed at the head-end, and it is unlikely that customer requirements will exceed the bandwidth of this link (in fact, such a network has moved to the other extreme of vast overprovision of bandwidth). This is efficient from a service organisation viewpoint, but, so far as is known, all studies in this country show such networks to be very costly. As optical-fibre technology matures and work practices are developed to enable fibres and optical devices to be handled on a routine basis in the field, such networks will probably become a practical proposition. BT has research and development programmes in hand to move as quickly as possible towards this goal, but it does seem to be premature to consider early deployment of single-star optical-fibre networks. Other countries however are attempting to force the pace: the French in the Biarritz scheme and the Germans in the BIGFON project.

An intermediate topology is the multi-star network. In this, groups of customers are connected by individual wideband links to wideband switch units in the field, which are connected to the head-end by trunk circuits. There is no bandwidth limitation in the customers links and there is a large degree of traffic concentration back to the head-end on the trunk circuits. The trunk circuit capacity can be cheaply and quickly augmented to provide additional capacity as growth of service and provision of new services requires it. The network therefore approaches the low cost of the tree network, but has no inherent bandwidth limitation and is compatible with a practical evolutionary strategy. This form of network is being actively developed by BT for early deployment.

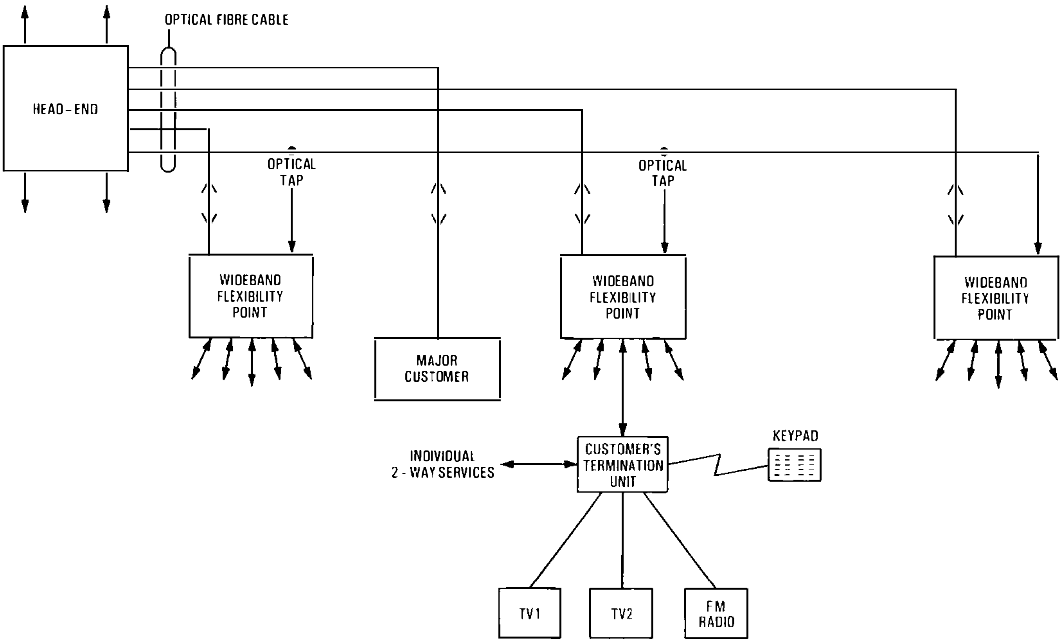


FIG. 1—Multi-star local wideband network topology

It must be stressed at this point that, although BT sees major advantages in the multi-star network for the provision of advanced services, it is only one line of development. Simple tree networks are the cheapest way of distributing multi-channel subscription TV and since in the early days this will be by far the major source of revenue, it may be difficult to justify the extra cost of the multi-star network. The extra cost is not large, but it will be significant in such a price-sensitive market. The way forward will be to exploit the advantages of the network and provide those additional services which are likely to have a high customer appeal, but which can be provided at low extra cost.

The chosen topology is illustrated in Fig. 1. It is basically multi-star, but has in fact elements of all 3 networks (tree, single-star and multi-star) to give a network well matched to the traffic demand of integrated services provision. The multi-channel TV service is transmitted to the wideband flexibility points (WFPs) by tree networks implemented in optical fibre and using optical taps to provide parallel connections. WFPs are also fed by a single-star optical-fibre network from the head-end to cater for individual customer connections either to video or videotex services or to 2-way telecommunications or data services. Customers who have a large amount of 2-way individual traffic, such as large businesses, are provided with their own individual pair(s) of fibres and would benefit from the greatly reduced costs of common provisioning.

The capacity of the WFP is an important factor. The larger it is the fewer the number of trunk routes required and the smaller the number of WFP sites. Against this must be set the penalties of longer secondary links and greater duct space demands. Current studies indicate a broad optimum at a capacity of about 300 customers per WFP.

TRANSMISSION MEDIA

Experience with optical fibres in the Milton Keynes cable-TV trial (described in a later section) has led BT to the conclusion that while optical techniques are suitable for the primary links (head-end to WFP), the technology has not yet matured to the stage where they can be considered for early deployment in the secondary links (WFP to customer).

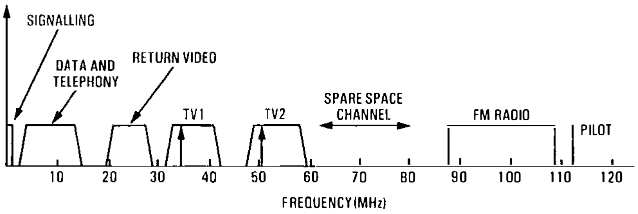


FIG. 2—Secondary link frequency plan

There is still some way to go in jointing techniques, circuitry and general work practices before fibres can be installed and maintained in a reasonably routine manner. However, the future lies with fibres, and BT is undertaking an active research and development programme.

In the primary links, fibres have much to commend them: the low attenuation means that line amplifiers are not needed; interference is negligible and transmission performance good; and duct occupancy is low, so over the long primary links duct augmentation will be rarely required. Furthermore, transmission systems with capacities of 4 or 6 TV channels per fibre have been developed and this, together with the lower projected costs for fibres, makes their use competitive with coaxial cables.

In the secondary links, as already outlined, fibre technology does not seem appropriate for the early systems and it is proposed to use coaxial cable. Coaxial cable is, in fact, quite suitable for this part of the network: lengths will be short (average about 300 m) so its higher attenuation is not a disadvantage; bi-directional transmission can readily be achieved and the technology and circuitry is well developed. Fig. 2 shows the proposed frequency multiplex arrangement. It can be seen that there is spare spectrum for the provision of as yet unidentified services, a useful adjunct in an evolutionary strategy.

THE MILTON KEYNES TRIAL

In June 1982, a multi-star cable-TV scheme (Fibrevision) was inaugurated at Milton Keynes. Although small, covering only 18 homes chosen by the Milton Keynes Development Corporation, the scheme incorporates many of the features already discussed as being appropriate to an advanced integrated services wideband local network. It uses optical fibre for both the primary and secondary links; incorporates intelligence at the wideband switch point to control and monitor the selection of channel or service; and provides shared Prestel usage and centralised accounting and network management. A brief description is given below. For a fuller description the reader is referred to reference 2.

Fig. 3 shows the basic system, excluding for clarity the special arrangements for Prestel and pay-TV access.

Head-End

All the available off-air TV programmes are provided from the existing head-end that serves BT's coaxial cable network at Milton Keynes. For the trial they are down-converted to baseband and separated into individual channels (0->6 MHz PAL with sound on the 6 MHz carrier). In addition, a channel is formed consisting of the frequency modulated (FM) radio programmes on carriers in the range 0->8 MHz.

Each channel is fed to its own optical transmitter unit (OTU-1), which uses pulse frequency modulation (PFM) and an edge-emitting LED source (850 nm wavelength with 30 nm line width).

Primary Link

A fully equipped 10 fibre cable (8+2 spare links) carries the channels (one per fibre) from the head-end to the flexibility point. This link is greater than 3 km in length and uses fibre of better than 4 dB/km loss and 400 MHz km bandwidth product.

Flexibility Point

Each incoming fibre terminates on an optical receiver unit (ORU-1) employing an avalanche photodiode receiver. The signal is demodulated to its PFM form and is input to a wideband switch which, under microprocessor control, can route any input to any output. The PFM outputs from the switch feed into optical transmitter units (OTU-2), which again use edge-emitting LED sources.

An Intel 8085 microprocessor scans the signalling input cards to look for a new customer request and controls the switch accordingly. Additionally, it receives automatic monitoring information.

Secondary Links

From the flexibility point a secondary link connects to each customer. This link consists of a 2-fibre plus 2-wire cable and has a length varying between 50 and 200 m. A single channel is again carried on each fibre, which has characteristics of better than 10 dB/km loss and 200 MHz km bandwidth product. Copper-coated strength members are conveniently used as the 2 wires to carry signalling information from the customer's end to the microprocessor control.

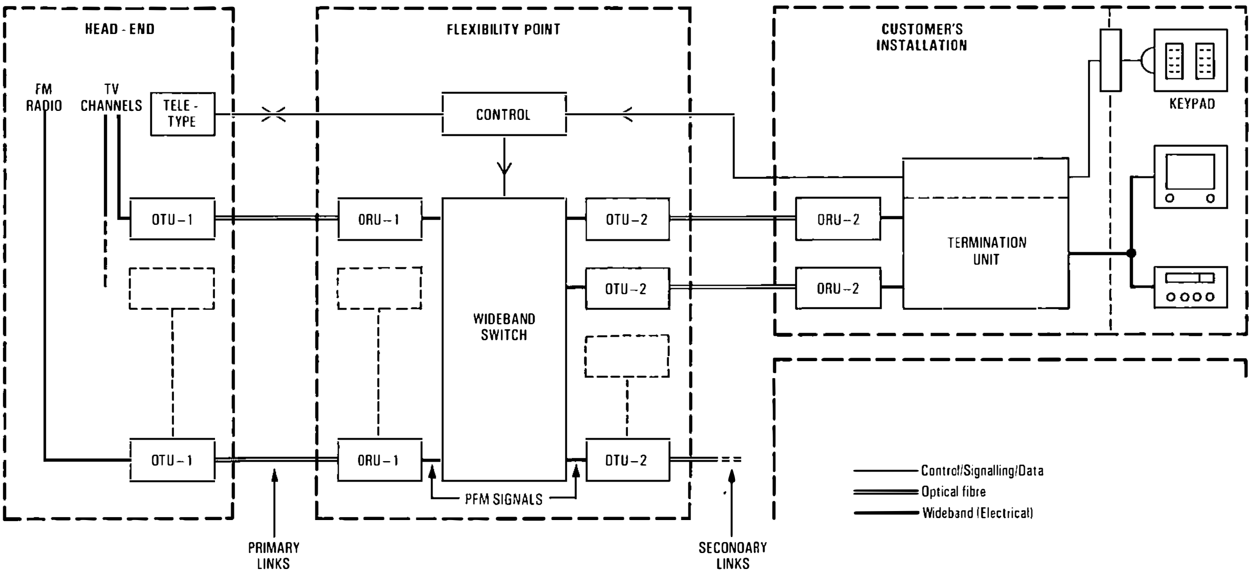
Customer's Installation

The optical receiver unit (ORU-2) for each of the 2 incoming links uses the simpler PIN diode detector prior to the FM demodulator stage. The resultant baseband TV signal is then up-converted to UHF so as to feed via coaxial cable to the normal aerial socket on a TV receiver. The customer chooses the required programme channel for each of the links by means of a press-button remote-control selector.

AN INTEGRATED SERVICES WIDEBAND NETWORK

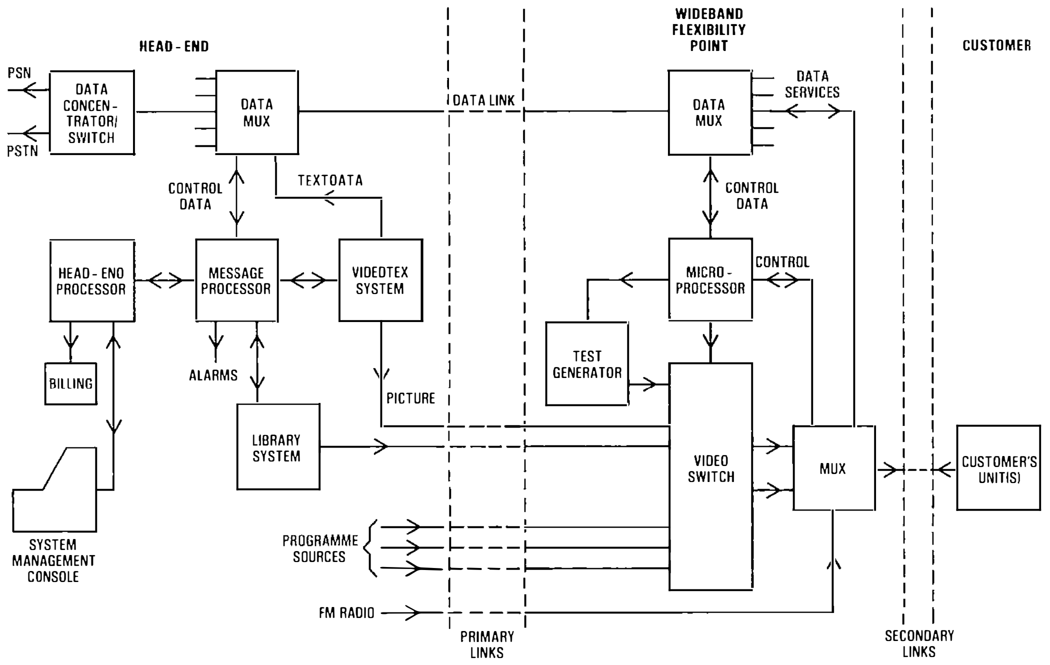
Various aspects of the proposed integrated services network have already been discussed: the use of the multi-star topology; the reasons for choosing optical-fibre primary links and coaxial cable secondary links; the frequency multiplex to be used on the secondary links; and the range of services to be provided. Further insight is best obtained by considering a block diagram of the control system shown in Fig. 4.

The control signals are routed to the WFP processor which controls the video switch and communicates with the head-end processor via time-slot 16 of a 2 Mbit/s data link. It is important that the WFP operates in a semi-autonomous



PFM : Pulse-frequency modulation
ORU : Optical receive unit
OTU : Optical transmit unit

FIG. 3—Fibrevision trial network



MUX : Multiplexor
PSN : Packet switched network
PSTN : Public switched telephone network

FIG. 4—Possible integrated services network control system

mode, providing basic service in the event of a head-end control failure.

The videotex system operates in a shared mode at the head-end generating pictures at the head-end and text at the WFP, thus sharing expensive equipment—a cost saving principle already discussed.

Data access to the packet-switched network and the public switched telephone network would be provided via a data multiplexer to those requesting the service, but later, if demand for the service grew, access could be via a concentrator. The data system shown uses an intermediate technology; later systems are likely to employ ISDN message formats and protocols, and interface with System X exchanges. As individual circuits are provided to customers, there is not the security problem of shared highways experienced on tree networks.

The head-end processor performs billing and high-level control and supervisory functions, communicating with the various elements of the system via a message processor. An important design requirement is to achieve a coherent fan-out of control. Thus the head-end processor controls the WFPs via multiple outputs on the message processor and at the WFP a main processor controls up to 10 microprocessors, each of which controls the data flow and video switching of 32 customers.

A major design task is the engineering of the WFPs. These must be compatible in size with existing street furniture, yet must perform complex switching, control and communication functions reliably in a hostile environment. This article does not permit a detailed discussion of the problems and solutions, but Fig. 5 gives a general idea of the proposed layout and structure.

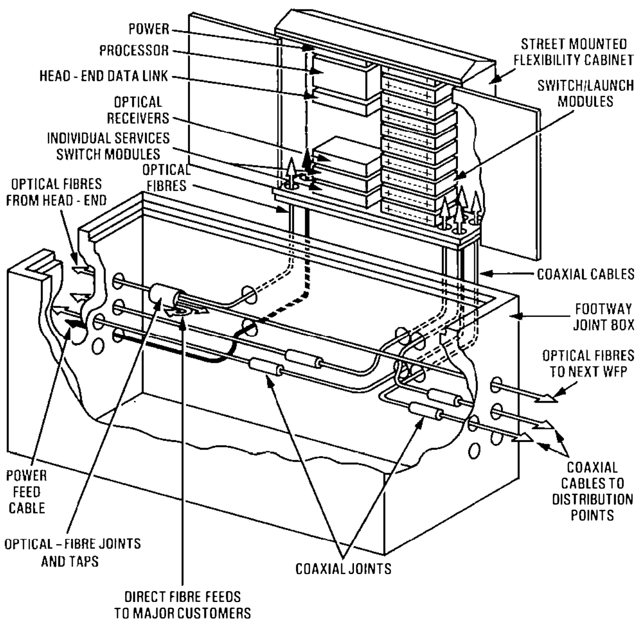


FIG. 5—Layout of wideband flexibility point (WFP)

CONCLUSIONS

Various advantages and disadvantages of tree and star networks have been discussed in this article. Undoubtedly the tree network is a cheap and efficient way of distributing multi-channel TV and, when combined with a sophisticated interactive control system, can offer a number of limited interactive services. However, when viewed from a tele-information viewpoint critical limitations are revealed, notably a limited capacity to provide individual services be they video or data.

The advantages of the alternative multi-star topology may be summarised as follows:

(*a*) There is no inherent limitation on bandwidth, thus a wide range of tele-information services can be provided and the system can evolve to provide new services without alteration of the basic network.

(*b*) No scrambling is required, which, in addition to being a major saving, provides noticeably better picture quality.

(*c*) Security to the customer is good in that individual circuits are provided for individual services. Security to the programme distributor is good in that access can be achieved only via the WFP switches making programme theft virtually impossible.

(*d*) The network is well suited to semi-rural distribution in that small towns and villages can be served by one or more stars and linked back to the distant head-end by low-loss optical-fibre trunks.

(*e*) Centralised control and switched access is compatible with flexible accounting, centralised billing and comprehensive centralised system management.

(*f*) Most of the intelligence is back in the network where the various control functions can be performed much more cheaply. The complexity of the customer's control box is minimised.

The disadvantage is that of cost. Estimates indicate that the cost of deploying a multi-star network is comparable with an advanced interactive tree network, such as the Warner QUBE system. However, when compared with a simple tree network the costs are higher since the savings from centralised intelligence and absence of scrambling are insufficient to offset the cost of individual links to each customer and field siting of WFPs. This brings us back to the basic commercial question—will the additional services that can be offered by an integrated services multi-star network have the earning capacity, particularly in the early days, to justify their deployment in preference to simple tree networks?

This is a critical question, since if multi-star networks do not find a place in the recabling of Britain, the opportunity will be lost for 30 years or more. No fully viable strategy has been identified for evolving from a tree network to a multi-star network.

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Book Reviews

Transmission Systems II (second edition). D. C. Green. Pitman Books Ltd. 148pp. 123 ills. £4·95.

This book is written to cover the Technician Education Council's (TEC's) standard unit in Transmission Systems II. It begins with an informative introduction to frequency theory and with an analysis of some of the more common transmission systems and their frequency ranges. This section of the book will be of some value to students studying Telecommunication Systems I as well as to those studying Transmission Systems II.

The section which follows deals fairly comprehensively with amplitude, frequency and pulse modulation, and with modulation techniques used in data transmission systems. The paragraphs on amplitude and frequency modulation will also be of some benefit to students studying Telecommunication Systems I. Students may well have difficulty in following the pulse-modulation and phase-modulation areas as the line drawings are not always easy to comprehend.

The principles of carrier selection, bandwidths, power transfers, filters and the decibel are all introduced and explained in some detail. A subsequent chapter deals with the composition of telephone lines and cables, and with the effects of their line parameters. Students should note that this chapter relates to Lines II and Line and Customer Apparatus I units, and that the Transmission Systems II Unit (TEC U81/746) no longer covers this area of study.

The chapter on 2/4-wire circuit theory is easy to follow and includes some notes on noise in line systems.

The final chapter covers frequency- and time-division multiplex systems. The frequency spectrum diagrams of the CCITT 12-channel group and the supergroup leads to some confusion when they are compared with the notes that are provided.

Numerous examples are provided throughout the book and each chapter contains a good selection of practice questions, and answers are provided near the end of the book. Some areas of the book delve, in my opinion, too deeply into the theory or practice of systems, and this may prove more of a hindrance than an aid to the student. Students who are frustrated by the complexities of any section of the book would be well advised to check the learning objectives of the unit before they become overwhelmed by the theory. Some of the line drawings have minor errors, but these should not cause students any problems to their understanding of the related theory.

The learning objectives of the Transmission Systems II programme are listed near the back of the book, and this listing relates to the TEC U81/746 programme, which is the latest programme for this unit. The contents of this book covers the U81/746 programme.

In general this book is a valuable aid to students studying the Transmissions Systems II unit.

N. C. WEBBER

Microelectronic Systems, Level 2. Ian Sinclair. Holt-Saunders Ltd. v+122pp. 86 ills. £2·95.

Written to cover the Technician Education Council's (TEC's) standard unit in Microelectronics Systems II, this textbook should prove a good choice for students studying the course.

The objectives of the U79/603 unit are adequately met in a logical manner, with each chapter meeting a general objective or covering a section of the unit. A summary, together with exercises consisting of questions on the subject, follows each teaching point and each chapter is rounded off by a test. However, these tests would have been of greater value if model answers had been provided as well. Many of the figures consist not of line drawings but of text. This is rather distracting, and it would have been better if the author had chosen not to highlight these items of text in this way but to just incorporate them into the main body of the book. The line drawings, however, are clear and well presented.

Although the S1-MPU-2 instruction set is used as an example of available instructions, the chapters on microprocessor programming are not limited to any particular microprocessor. The MENTA assessment unit is recommended in Appendix B of the book as a teaching aid for a course. Few individual students are likely to purchase such a machine, as it costs over £100 to buy, but, if used on a course, it would provide students with valuable practical experience.

Despite the criticisms made above, the book is highly recommended as either a course or reference book.

J. SALMON

Statesman—A Low-Cost Press-Button Telephone

M. G. HANSEN, C.ENG. M.I.E.R.E., and B. G. DOCHERTY, B.SC.†

UDC 621.395.61:621.395.631.3

Statesman is a new all-electronic telephone that has recently been introduced by British Telecom, but developed as a private venture by a consortium of UK manufacturers. This article describes the design concept of this low-cost electronic telephone and highlights some of the significant features of the instrument.

INTRODUCTION

The Statesman (Telephone No. 9000) is one of the 2 basic-range electronic press-button telephones that have been recently introduced by British Telecom (BT)[1]. The manner in which the development was conducted represents a radical departure from the traditional procedure of a BT-funded development contract awarded to a single contractor. Experience has shown that this traditional arrangement almost inevitably resulted in a design-by-committee approach, in which much time would be spent on resolving relatively minor details.

In the case of Statesman, however, the development was a private venture under the control of a consortium comprising TMC Ltd., The General Electric Company Ltd. and Plessey Company plc., but with close liaison between BT and the consortium to ensure that the product met the requirements of both the suppliers and BT as the customer.

Press-button telephones, which first became generally available in the early-1970s, have always been more expensive than dial instruments because sophisticated electronics are necessary to replace the humble dial, even though the more recent application of integrated circuit (IC) technology has enabled the component count to be reduced. Similarly, electronic replacements for the carbon microphone, although yielding maintenance savings through improved reliability, carried the burden of higher purchase costs. Statesman was, therefore, designed from the outset as a low-cost telephone.

OBJECTIVES

The primary objective of the Statesman development was to produce a press-button telephone having a manufacturing cost approaching that of a dial instrument.

This main objective was achieved by the incorporation of the following features and design criteria:

(*a*) a new custom IC incorporating both speech and dialling functions to replace the traditional components;

(*b*) simple physical construction involving minimal assembly time;

(*c*) low-cost speech and tone-caller transducers; and

(*d*) balanced trade-off between production cost and ease of on-site maintenance (a move towards the throw-away telephone).

DESIGN PHILOSOPHY

The simplicity and elegance of design of the 700-type telephone evolved over many years, and successive reductions in manufacturing costs have left the designer of the all-electronic telephone with a formidable task—the replacement of the electromechanical telephone with an instrument performing all the necessary functions, at a cost comparable with the original.

As referred to in a previous article[2], the piecemeal replacement of constituent parts or functional areas by their electronic equivalents frustrates the designer in achieving the primary aim of low cost. Statesman has, therefore, been configured as a completely new design, treating the telephone as a comprehensive whole, without particular reference to the discrete functional divisions of earlier designs.

ELECTRICAL DESIGN

The functions of the telephone are achieved by the use of 2 ICs, with a minimum of peripheral components. One of the ICs performs the tone-caller function, and the other both the transmission and the signalling functions. This second IC is unique and is a principal factor in the success of this instrument meeting its design objectives.

Tone-Caller IC

The tone-caller IC rectifies the incoming AC ringing current from the local exchange to derive a DC supply for the logic circuitry and output stage to the tone-caller transducer (Fig. 1). The circuit generates 2 tones: one at approximately 1·1 kHz and one at approximately 1·3 kHz; these alternate at a rate of 10 Hz and are used to drive the tone-caller transducer. The tone-caller transducer consists of a piezoelectric ceramic disc mounted in a plastic housing, which is fitted by clips to the base of the case. The housing acts as a resonator to enhance the sound output level, and has its opening covered by a mechanical shutter operating as a VOLUME control. The edge of this circular shutter protrudes beyond the edge of the case to allow for easy operation by the customer.

Transmission and Signalling IC

The transmission and signalling IC, which was custom designed for use in Statesman, contains both analogue and digital circuitry processed in n-channel metal-gate metal-oxide semiconductor technology. This technology has been used for many years to construct digital ICs—its low power consumption, low voltage requirements and high component

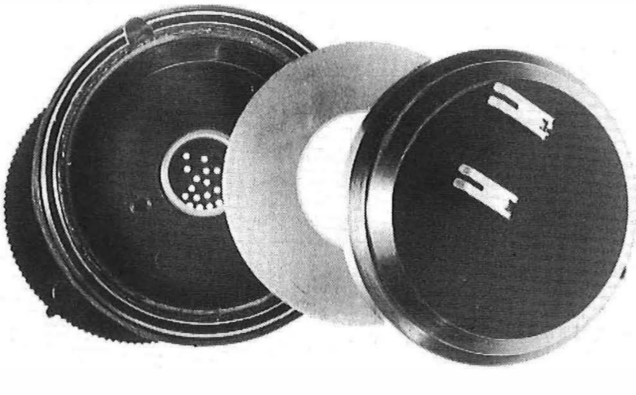

FIG. 1—Tone-caller transducer

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† Systems Engineering, Merlin British Telecom Business Systems

density making it ideal for switching circuits in telephone instruments, but processing variations and potentially poor noise performance have normally precluded its use for linear-circuit design. However, by applying sophisticated computer-modelling techniques, it was established that the adoption of different design rules for the linear section of the IC could overcome these problems. The IC did, however, undergo several iterations before a circuit suitable for large-scale production and capable of consistent performance was derived.

Fig. 2 shows the main functional areas of the transmission and signalling IC. The performance of the send amplifier is crucial, and presented the greatest challenge in terms of analogue circuit design. The send amplifier provides about 24 dB of gain, and it is essential that any noise introduced by this high-gain stage should be minimised. A low noise performance is achieved by the use of physically larger transistor elements in this section of the IC than in the digital areas. Fig. 3 shows this difference in scale.

The receive amplifier provides not only gain, but also buffering between the line and the receiver. The gain of both amplifiers is reduced when the comparison of a reference voltage with the voltage appearing at the telephone terminals indicates a line length of less than 3 km from the local exchange.

Circuit Operation

Fig. 4 shows a simplified block diagram of the complete telephone circuit. Amplified speech signals from the microphone are transmitted to line via the common-emitter amplifier formed by transistor TR1. Transistor TR2 is simply a switch which is saturated during speech and dialling MAKE periods, turning OFF only during the breaks between dialling impulses and line breaks.

The signal from the line is derived via a potential divider comprising resistors R1 and R2, and is fed into the receiver amplifier. The receiver amplifier line input is summed with a *sidetone* signal from the microphone amplifier to provide sidetone cancellation. There is no need to invert either of these signals as inversion occurs across transistor TR1.

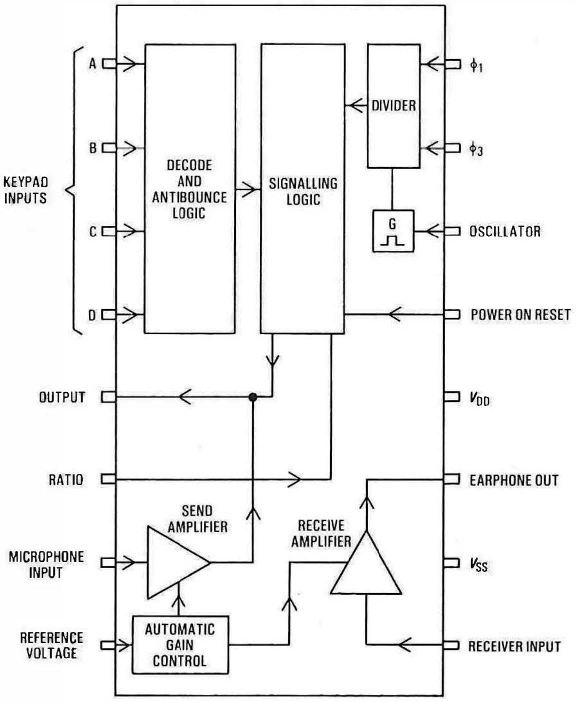
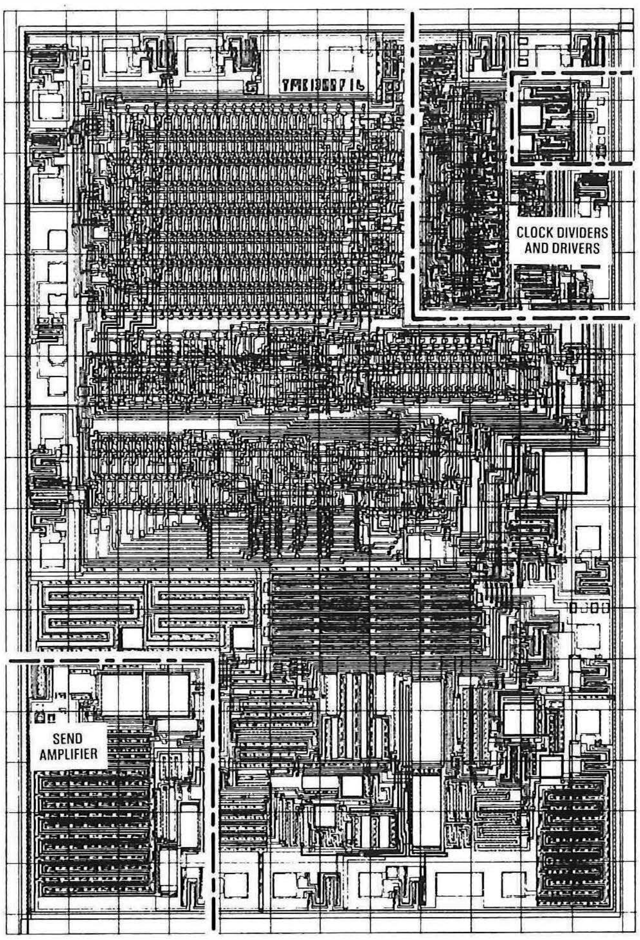


FIG. 2—Block diagram of tranmission and signalling IC



Note: comparison of the clock dividers and drivers section of the IC with the send amplifier section shows the difference in scale of the component elements

FIG. 3—Transmission and signalling chip
(Diagram courtesy TMC Ltd)

The emitter impedance, Z_e, is a scaled version, in magnitude, of the line impedance required for zero sidetone (Z_{SO}). This has been derived so that the sidetone sensitivity is minimised. Transistor TR1 provides an amplification determined by the impedance Z_e and the combination of resistors R1 and R2 in parallel with the line impedance.

The supply current for the IC flows through resistors R1 and R2. The impedance of the telephone is determined virtually by resistors R1 and R2 as transistor TR1 is a current source with a high impedance.

When a keypad button is depressed, the circuit changes from the TRANSMISSION mode to the SIGNALLING mode and the oscillator is energised. This oscillator runs at a frequency of 560 kHz divided down to 10 kHz to provide supply clocks for 4-phase logic. The microphone amplifier is disabled and the receiver amplifier is ramped down to a low-current state to prevent excessive clicks in the ear. The depression of the button is verified by an anti-bounce timer and, if valid, the required number is pulsed out to line.

During pulsing, the base voltage of transistor TR1 is lowered, turning OFF transistor TR1 and also transistor TR2 (as the base current of transistor TR2 is now removed). For the duration of this break in line current, it is essential that sufficient charge is stored in capacitor C1 to power the logic—it is for this reason that most of the transmission section is disabled. The IC can store up to 18 decadic digits in its memory in order to allow for the time differentials

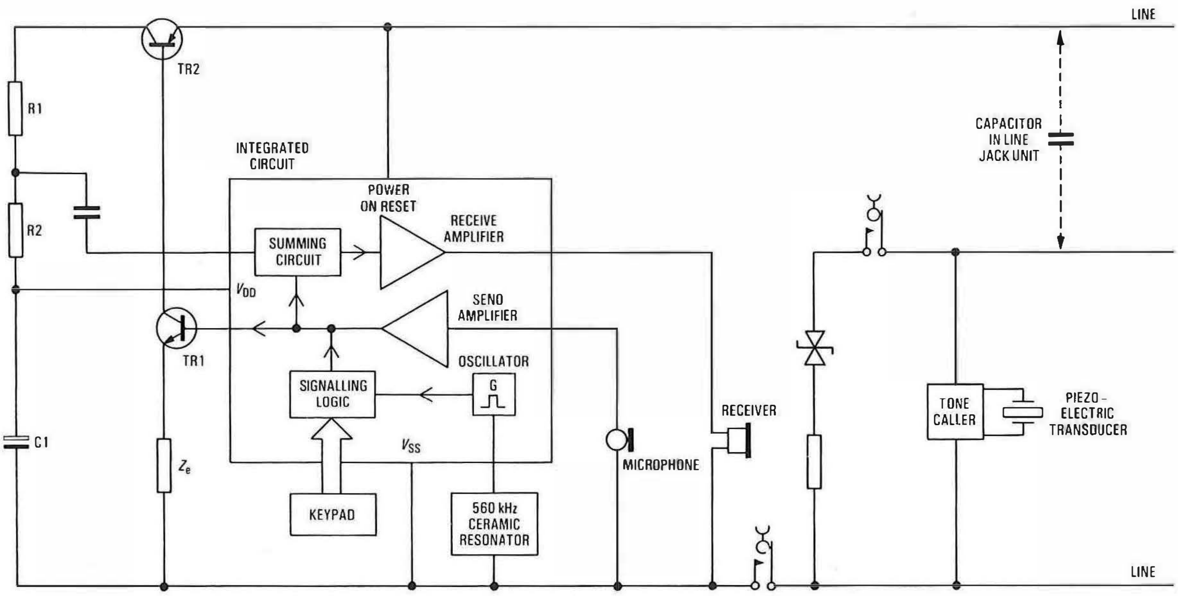


FIG. 4—Block diagram of telephone circuit

introduced between fast keying and the relatively slow pulsing-out required by the network.

When the telephone reverts to, or from, the SIGNALLING mode, a ramped transition from the low-current operation of the amplifiers to their high-current operation occurs. This ramping uses a switched capacitor integrator driven from the master oscillator, and prevents audible clicks in the receiver.

HANDSET

The telephone uses the BT Handset 16B, which has a known and characterised performance. The transducers used in the handset had to meet the dominant criterion of low cost consistent with good performance.

Two types of device have been adopted: a simple moving-coil type and a rocking-armature type; each being applied as either microphone or receiver. Both these devices offer the correct frequency response with low distortion, low inherent noise products and low AC impedance. The adoption of such low-impedance transducers avoids the need to include an impedance-matching circuit or, alternatively, to place the whole telephone circuit in the handset.

MECHANICAL CONSTRUCTION

The telephone circuit is laid out on a single printed-wiring board (PWB), (Fig. 5), that not only supports the electronic circuits necessary to perform the functions of the telephone, but also forms the mounting for the hook switch and RECALL switch (where provided), and the contacts of the keypad. Spring connectors moulded into the tone-caller transducer housing bear directly onto metallic pads on the PWB, avoiding the need for flexible wiring.

The keypad (Fig. 6) is of a particularly simple construction. The buttons are fitted into a button guide located in the case top. Beneath the keypad is a silicone rubber mat moulded such that under each button is a dome of rubber, to the underside of which is attached a nipple made from a conductive rubber isomer. Depression of the button brings the nipple into contact with a series of interleaved fingers of gold-plated track on the PWB, which forms the base of the keypad and, by bridging these fingers, completes the circuit corresponding to the button depressed. The shape of the dome and the mechanical characteristics of the rubber determine the feel and action of the keypad. The whole contact unit is effectively sealed by the mat, and has been shown to be reliable for more than 500 000 operations.

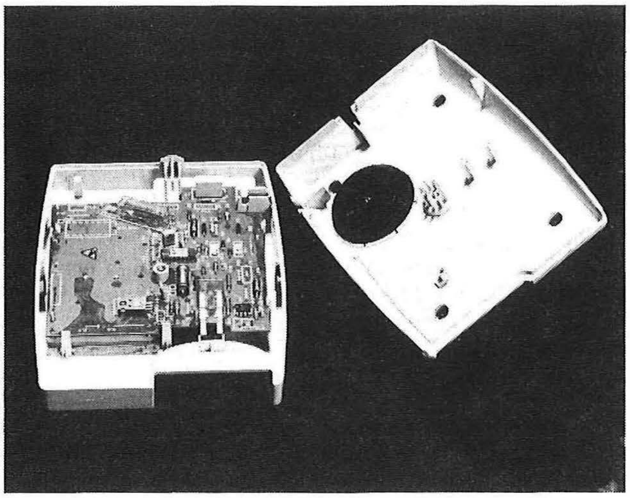


FIG. 5—Exploded view of telephone

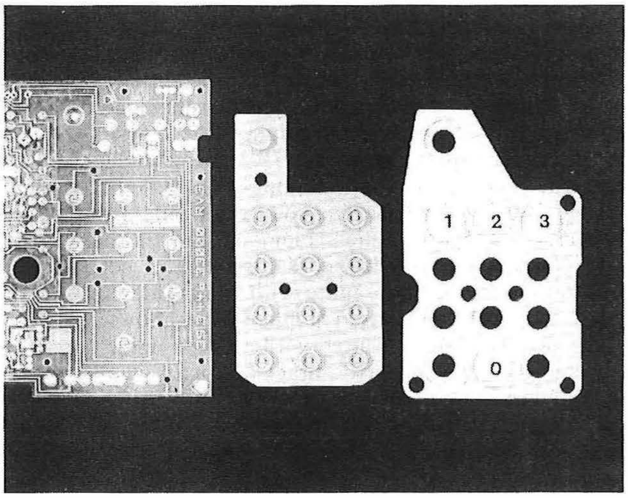
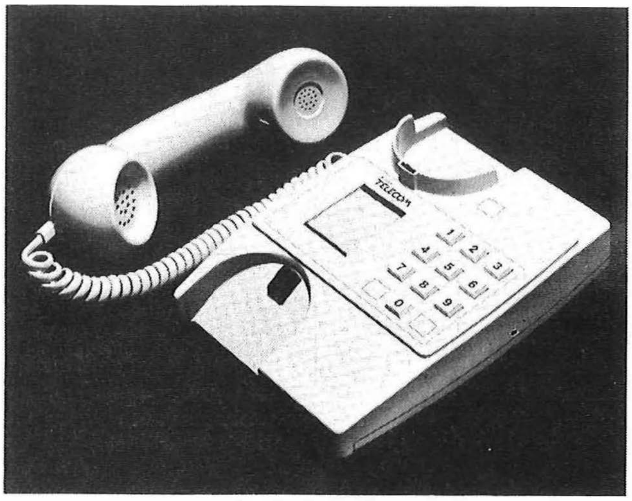
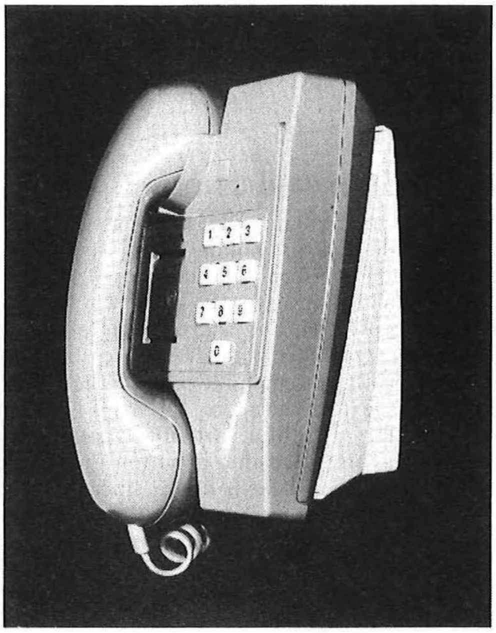


FIG. 6—Keypad



(*a*) Desk version



(*b*) Wall-mounted version

FIG. 7—Statesman in desk and wall-mounted modes

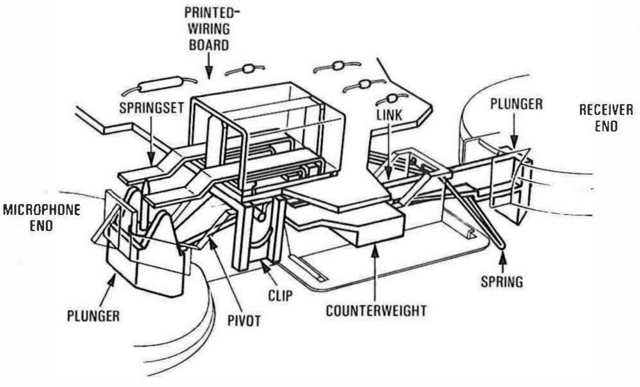


FIG. 8—Hook-switch mechanism

The hook-switch operating mechanism is designed to enable the instrument to be mounted in either the desk (horizontal) or wall (vertical) mode (Fig. 7). The springset is actuated by a plunger that is depressed by the microphone end of the handset when the telephone is in the desk mode. When the telephone is wall mounted, the actuating force is provided by the receiver end of the handset, which depresses a second plunger mechanically linked to the first (Fig. 8).

The case is constructed with the PWB sandwiched between the upper and lower case mouldings. The assembled board (with switches and keypad) is mounted on pillars and located securely by snap-fit anchors moulded into the base of the case. The line and handset cords are terminated by simple push-on connectors that mate with pins soldered onto the PWB. The top of the case completes the sandwich and the whole construction is secured with a single fixing screw.

A simple moulded plastic bracket is used when the telephone is wall mounted. The mounting plate of this bracket locates over the feet of the telephone, and the telephone is affixed to the plate and bracket by the single case fixing screw.

As a result of the substantial reduction in the number of piece-part items and the simplified physical assembly, the production time for the telephone has been reduced to about 42% of that for the equivalent 700-type telephone. This time saving is a major element of the overall cost reduction.

PERFORMANCE

The telephone has been designed to adhere closely to the performance specified by BT, and also to meet the relevant British Standards Institution (BSI) specifications.

The transmission performance of Statesman has been evaluated using the BT system of loudness ratings. Loudness ratings provide a repeatable objective assessment of subjectively perceived speech performance—the necessary measurements being quickly made by computer-controlled equipment. The impedance of the telephone is very closely centred on 600 Ω and is virtually independent of line current. The use of linear transducers and low-noise amplifier circuits has constrained the psophometrically weighted transmission noise to below −65 dBmp and the total harmonic distortion to a value of less than 7%. In comparison, carbon microphones may produce 15% or more harmonic distortion.

The telephone generates controlled and accurately defined pulses acceptable to all variants of BT pulse-detecting relays at all local line lengths. The pulsing performance of the telephone is within the limits set by BT and BSI standards.

CONCLUSION

The primary aim of the Statesman development—to produce a low-cost press-button telephone—has been met, and this has been achieved without any recourse to inferior performance and reliability. Substantial supply orders have been placed with the 3 members of the development consortium, and the telephone is now being manufactured in high volume.

Considering the radical departure of the design from its predecessors, trials of Statesman under field usage conditions have revealed only a few design weaknesses of a very minor nature. The necessary modifications have already been incorporated into current production.

ACKNOWLEDGEMENTS

The development of Statesman was a team effort, and acknowledgement is therefore made to the design engineers of TMC, GEC and Plessey. Particular credit must be given to those who applied their considerable skills in advanced integrated-circuit design and in innovative production engineering so effectively.

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The Problems of Connecting Aluminium Conductors

B. WILTSHIRE, M.SC., PH.D., C.ENG., M.I.MECH.E., M.I.M.†

UDC 621.315.55: 669.71: 621.315.68

Aluminium-conductor cables were introduced into the UK's telephone network more than a decade ago. Their use became economically viable at this time because of the escalation in the price of copper. Although its transmission properties are comparable with copper, aluminium possesses adverse physical properties which make it difficult to joint. This paper describes the fundamental properties of aluminium and the connection systems that have been devised to joint it. Further development work is described that has led to new types of connector giving a long-service low-resistance performance with aluminium conductors. This article is based on a paper presented at the Symposium on Reliability in Electronics, Budapest, Hungary, October 1982.

INTRODUCTION

Aluminium cables were introduced into the UK's external telephone network more than 2 decades ago. The use of aluminium cables became economically viable at this time because of the significant escalation in the world price of copper. In addition, as the transmission characteristics of aluminium cables could be tailored to be comparable with those of copper, it was envisaged that there would be no major technological problems in introducing these cables.

The problems of jointing aluminium, however, are quite different to those of copper. Copper cables were originally jointed by using mainly twist, solder and screw termination, which gave long-service low-resistance performance. But with aluminium, because of its reactive surface behaviour and adverse physical properties, it was not possible to continue with all of these methods, as joints would quickly deteriorate in service. New methods of jointing were therefore devised, some of which proved to give near perfect joints, while others were acceptable only as compromises. Aluminium cables now constitute a major part of the external cable network, but their jointing properties are still not fully understood. This has resulted in a continuous development to produce suitable connectors which will give good service performance.

This article describes the introduction of aluminium cables into the network and includes a review of the physical properties which make them difficult to joint. This is followed by a description of jointing systems that are currently available. Finally, modifications are described that have led to the development of new connectors for aluminium cables, which can be shown to perform to a high standard.

ECONOMICS

Copper has been used as a conductor for telephone cables since before the turn of the century. It is a natural choice, because it has good electrical characteristics, is inert, and is easy to handle and joint. Aluminium also has good electrical characteristics[1,2], but its adverse physical properties, including rapid oxidation rates and lack of ductility, have normally made it a second choice for telephone cables.

The price of copper was for many years low and stable, but, during the last 2 decades, it has fluctuated and occasionally risen to high levels. In contrast, the price of aluminium has remained relatively stable. It was not surprising, therefore, that a change from copper to aluminium was suggested, purely on economic grounds. In fact, during the mid-1960s, the difference in price between the 2 metals was sufficient in the UK to justify the introduction of aluminium. Coupled with this, aluminium was in plentiful supply and had a relatively stable price since there were worldwide deposits of bauxite, the ore from which it is obtained. Consequently, it was free from the strategic and political influences which affected the supply of copper.

In retrospect, the economic argument for using aluminium was justified because the price of copper continued to rise to an extent that in 1974 it was, at about £1300/t, over 3 times the 1972 price. Aluminium, over the same period, rose from about £250/t to £325/t.

HISTORY

The first production cables appeared in 1967. These consisted of 0·8 mm and 0·6 mm diameter pure-aluminium conductors in the ¾-hard condition. (The term *¾-hard* refers to the amount of work-hardening that the conductors are given prior to being made up in the cable.) Work-hardening increases the tensile strength of the material, needed for cabling activity, but with a consequent sacrifice in ductility. In fact during the laying of the original cables, severe cabling and jointing problems were encountered, because of this lack of conductor ductility.

It was necessary then to modify the subsequent cables to improve their ductile behaviour. Eventually, an aluminium-alloy cable was introduced, which, although more expensive, had ductility characteristics more comparable with copper; that is, the elongation was increased from almost zero to 10%, and the tensile strength was the same as copper. Furthermore, the range of wire sizes was modified so that, by the early-1970s, one size only (0·5 mm in diameter) was available.

TRANSMISSION CHARACTERISTICS

For many years it has been appreciated that aluminium would be a suitable substitute for copper for telecommunications transmission purposes. It has the advantage of lightness, but its resistivity is somewhat greater than copper. From Table 1, it can be seen that the specific resistance of aluminium is 2·76 and that of copper is 1·72, so that for equivalent resistance, aluminium wires must be 1·27 times the diameter of copper. However, the specific gravity of aluminium is only 2·7 compared with 8·89 for copper. Thus

TABLE 1
Transmission Characteristics of Copper and Aluminium

Property	Copper	Aluminium
Specific gravity	8·89	2·70
Weight for equal volume	1·00	0·30
Conductivity	100	62
Specific resistance	1·72	2·76
Area ratio for equal conductance	1·00	1·64
Diameter ratio for equal conductance	1·00	1·27
Weight ratio for equal conductance	1·00	0·49

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† Research Department, British Telecom Headquarters

for equivalent resistance, the weight of an aluminium wire is about half that of copper. Alternatively, for the same weight, aluminium provides a conductor almost twice the length of that of copper of the same diameter.

In addition, the advantages of aluminium conductors are due in part to the higher mass conductivity of aluminium over copper. On a weight basis, aluminium has over twice the conductivity of copper; on a volume basis, it has about 65% of the conductivity of copper.

PHYSICAL PROPERTIES OF ALUMINIUM

The jointing of aluminium-conductor telephone cables has not been completely successful when conventional methods have been used. These methods, designed for copper conductors, have not been able to accommodate, without modification, the different mechanical and chemical properties of aluminium. The properties which must be considered are: the difference in thermal expansion coefficient, the increased chemical activity because of further separation in the electro-chemical series, the creep and stress relaxation rates and the rapid formation of oxide films. Of these properties, the latter two are arguably the most important factors in the design of long-service low-resistance joints.

Oxidation

The unique physical properties of aluminium must be carefully considered when designing connectors for aluminium wire. Aluminium acquires a thin film of oxide (normally Al_2O_3) virtually instantaneously on exposure to the atmosphere. This film is not only a good insulator, but is hard and adheres firmly to the surface of the wire. Although the film is thin, once formed it prevents the aluminium from reacting further. This behaviour can be contrasted with, for example, metals such as silver, copper or tin, on which the oxide films form slowly and are easily removed.

Any method of jointing aluminium, therefore, must be capable of removing or breaking through the oxide film and preventing it from reforming on the contact surface. Making the initial contact is perhaps not difficult because the oxide film is brittle compared with the substrate. In a typical cable connection, as pressure is exerted on the aluminium to make electrical contact, the substrate is plastically deformed, but the inelastic oxide film cannot follow the deformation and so breaks. Thus the oxide film is penetrated and good electrical contact is established.

At this stage, and for the rest of the service life of the connection, it is important to maintain a minimum contact stress. If this is done, then the joint gives a good service performance because progressive oxidation ceases to occur. But, if the minimum contact stress cannot be maintained, re-oxidation of the mating surface occurs and leads to increased contact resistance.

Creep and Stress Relaxation

Creep and stress relaxation occur in varying degrees in all metals. There is some confusion as to the separate roles of creep and stress relaxation, but in connectors both have the effect of lowering contact stresses. In general, creep is a continuing yield at a constant stress, where yielding is a result of a slow atomic diffusion mechanism which is dependent on time and temperature. Stress relaxation is also time dependent, but is not accompanied by a dimensional change. Both creep and stress relaxation can result in a change from elastic to plastic strain, which ultimately has the effect of reducing the contact pressures in the joint to a point where it may fail because of excessive contact resistance.

Aluminium exhibits a much greater degree of creep and stress relaxation than does copper. In fact, results have shown that in copper, this creep, or cold flow, ultimately decreases to a low value. Aluminium, however, yields to the stress almost indefinitely.

CONNECTOR DESIGN

The requirements for any design of connector to successfully joint aluminium can be summarised as follows:

(*a*) the joint should be designed so that there is sufficient residual elastic energy to compensate for any stress relaxation of the aluminium conductor in service, and

(*b*) the intimate contact areas should not be exposed to oxidation or corrosion.

It is the combination of these 2 factors which determines the successful performance of a jointing system.

Apart from the mechanical design of the joint, there are a number of factors which contribute to good service performance. For example, the connector body can be designed so that the aluminium conductor is securely anchored just before entry to the joint. This fixture is known as a *strain relief*. It reduces the risk of handling or vibration causing the brittle oxide film around the contact interface to crack, which would result in reoxidation and increased contact resistance.

Suitable design of the connector casing, plus the use of water-repellant grease, can to a large extent eliminate moisture from the contact area. This should stop or slow down any galvanic corrosion effects which may occur between the different metals in the joint. On the contact faces themselves, a number of coatings can be used to improve the contact behaviour; these include tin[3] and indium[4].

Tin Plating

Tin is a commonly-used connector plating material for static copper contacts where relatively-high contact pressures are applied. Traditionally, it has been used on copper-based connectors to protect contacts during storage, because unplated copper alloys very soon form a tarnish which leads to a high contact resistance. The tin coating itself, as with most non-noble metals, readily forms an oxide (SnO_2) on contact with air.

The feature that makes tin so useful as a plating material for contacts is the relative ease with which the oxide film can be mechanically broken through to make low resistance metal-to-metal contact. Experiments have shown that a contact force as low as 30 g can break the oxide.

Tin-plated joints have been used successfully on copper cables, but on aluminium the results have been variable. As discussions in further paragraphs will show, tin plating appears to work well on some designs of aluminium joints, but not on others.

Indium Plating

Indium is a very soft inert metal, which has been used with some effect to improve the contact properties of aluminium. The mechanisms by which it enhances an aluminium connection are not fully understood, but in practise it works effectively. Indium has a very-low yield strength and is soft and ductile. It does not oxidise readily and adheres to other surfaces including aluminium and aluminium oxide. Furthermore, as it does not work harden, it exhibits ideal plastic behaviour.

The mechanism of the protection that indium gives to an aluminium joint is thought to be as follows. When contact with the aluminium wire is established, the oxide film is disrupted, and this exposes bare aluminium to which the indium adheres. This provides a gas-tight seal and prevents re-oxidation of the aluminium. Test results on indium-plated aluminium connections indicate that the initial contact resistance is reduced, and that it remains stable over a long period.

EXISTING CONNECTORS

Two types of connector are currently used in the network to

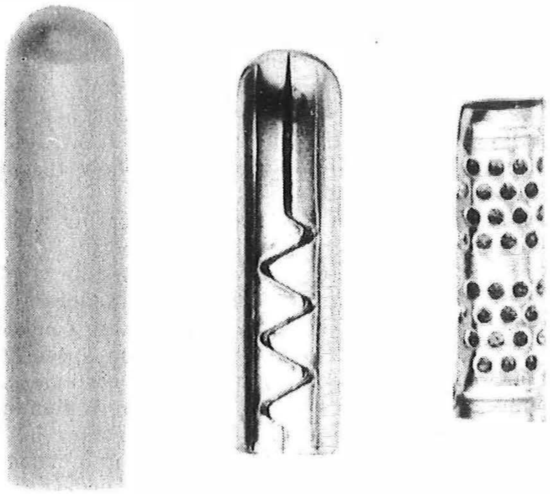

FIG. 1—Butt crimp, or B-wire, connector

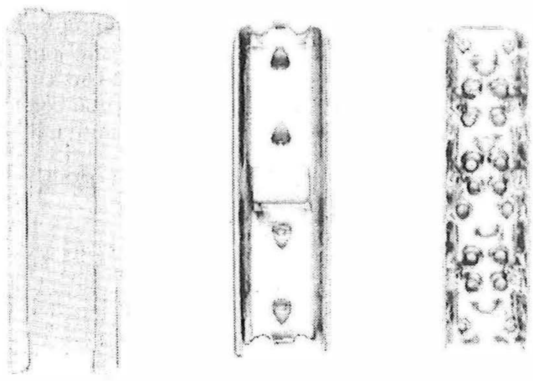

FIG. 2—In-line crimp connector

connect aluminium conductors: butt crimp (see Fig. 1) and in-line crimp connectors (see Fig. 2). Both connectors operate on the insulation-piercing crimp principle.

Butt Crimp Connector

The butt crimp or B-wire, connector is basically an adaptation of the American Bell connector and consists of: a cylindrical inside liner, a brass sleeve and a polyvinyl-chloride (PVC) jacket. The tin-plated phosphor-bronze liner is perforated, to give sharp tangs on the internal surface. The liner is surrounded by a soft brass tube which, in turn, is encased in the PVC jacket. The connector is supplied grease filled for weather protection.

In operation, the conductors to be joined are inserted into the connector, with the insulation intact. A hand tool is then used to deform the crimp to the desired dimensions. In fact, the tool is designed so that it cannot be released until the correct degree of crimping has been achieved. Electrical connection is made by the sharp tangs piercing the insulation and penetrating the surface of the conductors. In connections to aluminium conductors for example, this jointing pressure is sufficient to break the hard surface oxide and form intimate metallic contact with the substrate.

In-Line Crimp Connector

The in-line crimp consists of 3 U-shaped parts which nestle inside each other. The inner liner has perforations on the base and side walls which result in an array of tangs protruding on the inner surface. The liner material is again tin-plated phosphor-bronze. Surrounding the liner is a further tin-plated phosphor-bronze jacket, which in turn is encased by a PVC channel. The in-line connector is used in conjunction with an automated jointing machine, and is generally used grease free on dry-air pressurised cables.

In operation, the connectors are joined together by the plastic U-sleeve and mounted in a magazine to be fed to the jointing machine. The wires to be joined are laced unstripped into the connector, and then the hydraulic action of the machine folds the side walls on to the base. The detailed jointing action operates on the same principle as the B-wire connector. In both types of crimp, once initial contact is established, the elastic stored energy in the deformed crimp maintains a contact stress during service. The majority of this elastic energy is provided by the deformation of the outer metal sleeve, which bears down on the inner lining like a spring and keeps a positive load on the penetrating tangs.

Service Performance

Fig. 3 includes a comparison of the performance of the butt and in-line crimps used with aluminium wire during laboratory environmental tests. These are standard tests consisting of temperature cycling and heat soak, and are used to predict connector service performance. For comparison, the performance of a screw terminal is also shown; this exhibits the classical result of stress relaxation, decreasing contact stress, and increasing contact resistance. The crimp results indicate that the performance of the butt crimp (12 mΩ increasing to 200 mΩ) is not as good as the in-line crimp (constant at 7–8 mΩ). In fact, it shows a worse performance than that of the screw terminal.

On first analysis, it is difficult to decide why there is such

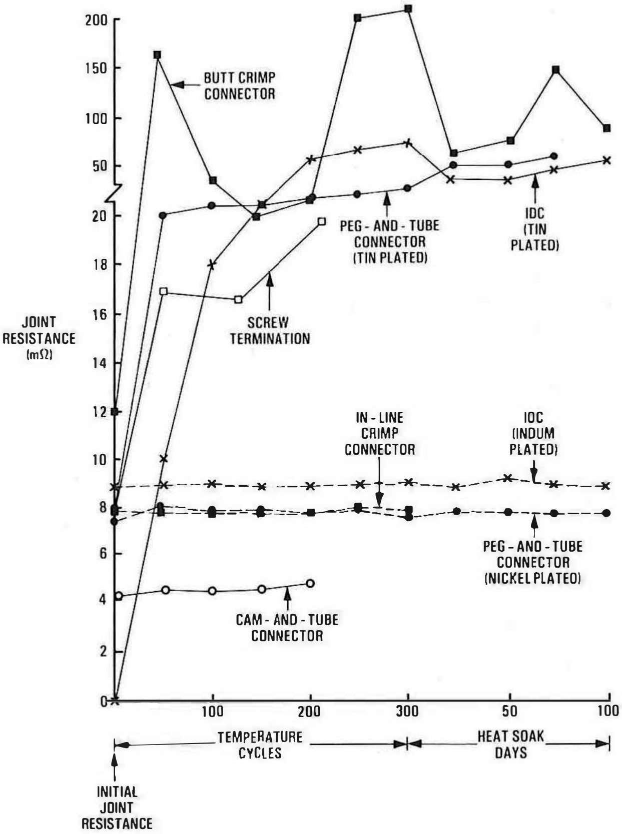

FIG. 3—Environmental test results

a difference in results. Both crimp connectors are tin plated and have aluminium (and insulation) in the joint. Furthermore, the butt crimp is greased filled whereas the in-line crimp is dry. This difference in results is probably due to a combination of the following:

(*a*) The butt crimp was originally designed for copper conductors only. It has perforations which are identical in size and are arranged in a regular pattern, but there is no means of aligning the wires to be jointed. The in-line crimp, however, was designed specifically for aluminium conductors. The location of the tangs is such that the wire is aligned prior to crimping to ensure maximum contact and to minimise the amount of plastic insulation in the structural path.

(*b*) The deformation stresses generated in the hand-tool-jointed butt crimp are lower than that in the machine-jointed in-line crimp. In both designs stress relaxation lowers the contact stress at the interface between the aluminium conductors and the tin-plated parts of the connector. In the butt crimp, with the lower initial deformation stress this allows re-oxidation to occur.

In general, the performance of the in-line crimp is good, but that of the butt crimp is only fair. Up to now, the performance of the butt crimp has been acceptable in the network; however, with the increasing use of digital transmission, it has become necessary to analyse critically joint performance. For example, very-low *wetting* currents (of about 4 mA) are used in a digital system, and so high-resistance joints can lead to a loss of transmission. New British Telecom (BT) specifications now limit the allowable resistance rise in a connector to 2·5 mΩ, over the environmental test period. This is a performance that can be met by the in-line crimp, but not by the butt crimp connector.

FUTURE JOINTING SYSTEMS

Much effort in BT has recently been aimed at the evaluation of many types of insulation-displacement connector[6] (IDC). These discrete connecting devices are quick and easy to install in the field and technically have the potential for performing well when used with aluminium conductors. Currently, these devices are being field assessed for use in the network.

Typically, an IDC consists of a grease-filled plastic body (normally PVC or polycarbonate) in which is housed a split-beam connecting element, made of a copper-based alloy (see Fig. 4). In operation, the wires to be connected are inserted unstripped into the connector body, and the element is brought down onto the wires. This action forces the split beams to displace the conductor insulation and straddle the wire to make electrical contact.

For external use, a U-shaped element containing 2 pairs of split beams has been adopted. The purpose of this is twofold: the split beam nearest to the connector entry port acts as an anchor for the wire; and the second beam, which has a narrower slot width, makes the electrical connection. As this second beam is forced over the conductor, it shears away the oxide film at each side so that intimate electrical contact with the substrate is ensured. After connection, the remaining elastic strain energy in the element maintains a positive spring load on the conductor. To a limited degree the displaced legs of the element will follow the stress relaxation of the aluminium conductor.

Laboratory tests have shown that the coating which is applied to the connecting element is important to field performance. Early IDC devices were designed for connecting copper and had tin-plated elements. In general, the performance of these connectors on aluminium conductors gave results which were well outside the new specification (see Fig. 3). However, it is worth noting that certain designs of tin-plated IDCs do appear to work on aluminium conductors.

In general, the problem of connecting aluminium conductors is solved by using indium plating. As described earlier, indium seems to offer protection from re-oxidation on aluminium, even when the contact stresses are low. Fig. 3 shows such a result; that is, the rise in contact resistance is negligible during the period of the laboratory test.

OTHER SYSTEMS

Another connection system for aluminium conductors, which has proved promising in principle, is the *smear* joint. Two types of these connectors have been assessed: a cam-and-tube connector[7] (see Fig. 5) and a peg-and-tube connector[8] (see Fig. 6). The cam-and-tube connector is manually oper-

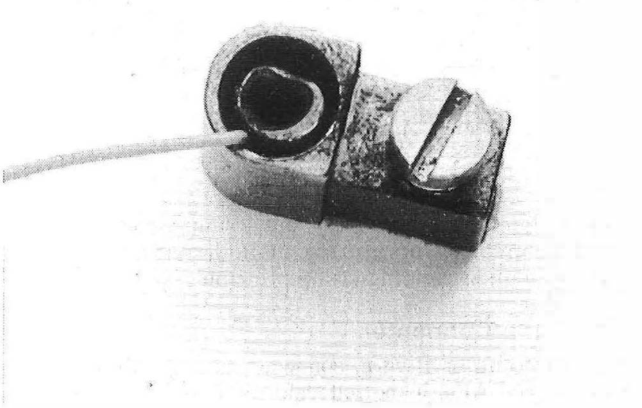
FIG. 5—Cam-and-tube connector

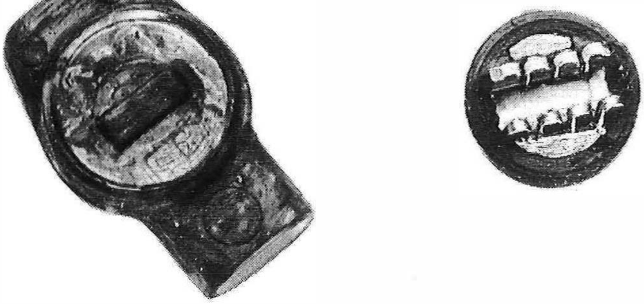
FIG. 4—Insulation-displacement connector

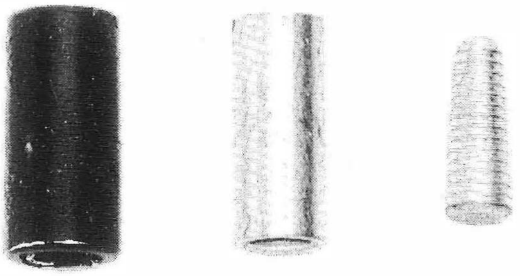
FIG. 6—Peg-and-tube connector

ated by a screw, whereas the peg-and-tube connector is hand-tool or automatic-machine jointed. Both devices operate on the principle of the jointing action smearing out the conductor to give a large contact area and a high residual contact stress.

In the cam-and-tube device, connection is achieved by the rotation of the cam, which picks up and grossly deforms a single conductor around the inside of the tube. This removes the oxides on both the aluminium conductor and the brass connector body, and ensures intimate metallic contact. Fig. 3 also shows test results for the cam-and-tube connector where the contact resistance has remained stable over the test period.

In the peg-and-tube connector, connection is achieved by a peg being forced into a tube, and this action simultaneously smears out the 2 trapped conductors. It is interesting to note that these devices can be used with aluminium conductors, provided that the connector is nickel plated. Standard tin plating gives unacceptable results (see Fig. 3), and although nickel is not considered a good contact material because it has a hard, almost impenetrable, oxide (NiO), in this instance, it appears that the nickel in the tube acts as an inner shell to bind the 2 aluminium wires more tightly together. The test results for the nickel-plated connector (see Fig. 3) show a negligible rise in contact resistance over the test period.

CONCLUSIONS

The change-over from copper to aluminium cables over a decade ago gave rise to many unexpected jointing problems. Aluminium is a reactive metal, and has unique physical characteristics that must be understood when jointing systems are being designed. The butt crimp, or B-wire, connector has been used as a standard hand termination, where machine jointing cannot be used. Its service performance has been an acceptable compromise up to now, but it is unlikely to meet new specifications for the performance of joints.

A continuous programme to develop suitable aluminium connections has been in progress. Initially, this has produced the machine-jointed crimp, which works well with aluminium conductors. More recently, a family of IDCs have been developed. These connectors, with a suitable selection of protective contact coatings, have proved to give long-service low-resistance joints on aluminium conductors.

ACKNOWLEDGEMENT

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British Telecom Press Notices

HEBRIDES RADIO

Hebrides Radio—a seafarers' radio station to aid safety at sea—was brought into service by British Telecom International (BTI) in September last year.

The station provides 2-way ship-to-shore communications and operates 24 hours a day, 7 days a week, over a 400 km radius in the Western Isles and eastern Atlantic. In addition to commercial shipping, Hebrides Radio also benefits owners of leisure craft.

The new station is remotely controlled from Stonehaven, Kincardineshire, and provides shipping with radio-telephone and radio-teleprinter services, maintains a distress watch and broadcasts weather reports and warnings of navigational hazards. It also handles personal calls.

The radio-telephone and radio-teleprinter services are provided by Hebrides Radio from 2 locations: one at Aird Uig, housing the medium-frequency (MF) transmitters, and the other at nearby Forsnavel, with the very-high-frequency (VHF) transceivers and MF receivers.

BTI operates 10 short- and medium-range radio stations throughout the UK, together with 20 short-range remotely-controlled stations similar to Hebrides Radio. The new station supersedes an MF-only service previously based at Oban.

NEW GENERATION OF MODEMS

British Telecom (BT) has introduced a new family of ultra-compact modems for the following Datel data transmission services: Datel 1200 Duplex, Datel 1230 Duplex, Datel 2400 and Datel 2400 Duplex. The new modems make extensive use of microchip technology to combine small size and modest power requirements with comprehensive facilities. Each modem is built on a single printed-wiring board and can be incorporated in various styles of equipment housings; for example, BT's new Datelphone—a new-style Ambassador telephone with a built-in modem.

Another new product is the Data Auto-caller, which enables a data terminal or computer to send and receive calls over the public network using the CCITT V25 parallel or V24 serial methods of operation. With the Data Auto-caller a customer can connect a computer or intelligent terminal to any CCITT standard modem and collect or send data, for instance overnight, entirely automatically by telephone.

BT is now offering a network-management package consisting of a combination of computer software and hardware for monitoring and testing data networks. Various levels of control and information facilities, tailored to meet the customers' exact requirements, can be provided to monitor and, when necessary, reconfigure data networks.

What Kind of Future for the Post Office?

Keynote Address to the Institution of British Telecommunications Engineers

R. E. DEARING, C.B.†

UDC 656.8 "313"

This address was given by Mr. R. E. Dearing, Chairman of the Post Office (PO), to the London Centre of the Institution of British Telecommunications Engineers on 27 October 1982. In his address, Mr. Dearing discussed the future expansion of the postal business. He highlighted the important contributions that engineers in the PO are making to this development, and described many examples of new technologies that are being harnessed to provide new services.

The subject for my talk this evening is, "What Kind of Future for the Post Office?"

I decided on this subject with some confidence because I knew that by the time I gave the address, I should have ample briefing for it. To be explicit, we had decided at the beginning of the year that we would make the subject for this year's Children's Letter Writing Competition, "A Letter to Someone in Another Planet". In response we had 146 000 letters, and I think it is going to take us about 2 centuries to deliver them. I can therefore say with confidence that we have a long-term future.

In my early days, I did in fact earn my living as a statistical forecaster. It was rightly a somewhat meagre living, and I wonder what the Head of the Post Office of the day, Sidney Buxton, would have had to say on this subject if he had been addressing you in the year of your formation in 1906. I wonder if, after the explosive rate of growth in the postal service since Rowland Hill's innovations in 1840, resulting in an increase in the number of letters posted from a mere 50 million a year to 2000 million by the turn of the century, there was any likelihood that he would have predicted not only the explosive growth of the telephone system and the telecommunications industry that has come with it, but a continuing brisk rate of growth for the postal service, which between the turn of the century and 1980 has grown from 2000 million items a year to some 11 000 million items a year.

MANS' NEED FOR COMMUNICATION

I do not believe it possible that anyone could have foreseen the hunger and the need for communication. But looking at the history of man, his whole development—the way in which each man has drawn upon the wisdom of his neighbour and upon the achievement of previous generations and other nations—has been through the art of communication. The better the systems of communication the more competent, the more powerful, and the richer mankind has become. I do not see that factor changing in the next 80 years. I say this not only because mans' need to satisfy his ever-growing material needs depends on it, but also because the practice of communication is part of the essence of the human being. None of us wants to inhabit a world alone—we need other fellow beings with whom to interact through communication.

My first and fundamental building block is, therefore, that the Post Office (PO) is part of a massive growth industry. And I would go as far as saying it is the one industry of all where secular growth can be confidently predicted, subject only to the awesome eventuality of Armegeddon overtaking the world. The issue for Posts, therefore, is whether it can share in this growth or whether this particular form of communication will progressively be overtaken by telecommunications.

Can I say at this point that I am consciously focusing for the present on the letter mail part of the PO and leaving for subsequent discussion parcels, the counter services, and National Girobank.

Well, one thing I did learn from my early days as a forecaster is that while we have enough relevant information from the past and the present to venture predictions for a limited period ahead—the amount depending on the particular factor we are trying to forecast—the further ahead we try to look, the less valid it is to extrapolate from past or current experience. Nor do we have the knowledge to assess consumer preference for products that have not yet been presented to them.

In our case I think it is possible to say, within 95% confidence limits, that the postal business has the capacity to keep growing during the next 5 years and to hold its own in the following 5 years. You will notice I am not saying that growth will be an automatic gift: I am saying Posts has the capacity and opportunity to grow. Beyond 10 years, I would not care to attempt to forecast trend curves, because I cannot assess the products on the market-place with sufficient certainty or, more importantly and more difficult, assess the customers' reaction to them. But perhaps the most important factor in determing the future growth of the postal business in the 1990s would be the vigour with which Posts itself harnesses the new communications technology to its own business, and I will touch on that later.

THE NEXT 5 YEARS

Let me first deal with the next 5 years. In assessing the potential for Posts in this medium-term period, I can draw on 3 factors:

(*a*) market research,
(*b*) current experience in the market place, and
(*c*) experience overseas.

All three combine to confirm the potential for growth.

This is not to say that all segments of the mails market will be growing: some in recent years have been declining. Indeed, within the overall mails market there is far more change than the laymen would ever imagine. Taking the PO's business as a whole, it has been said that around half of the business we are handling today did not exist or was only in embryonic form 30 years ago.

Taking first market research, our studies show the potential for growth in financial mail and in direct mail. Direct-mail selling now accounts for 11% of postal volume and it is the fastest growing advertising medium. This reflects in part its growing price advantage over other media and its increasingly proved effectiveness. As a result, the volume of

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† Chairman, The Post Office

this type of mail has doubled over the last 5 years. Even so, we only have 10% of the advertising market, and our recent success rate, the effort we are putting into developing the technology and the experience of overseas postal administrations, confirms that there is a lot of potential growth ahead of us here.

We have had external consultants look at financial mail, which itself is a complex market which breaks down into a sizeable number of segments. But taking that market as a whole our outside advisers show that even looking as far as 10 years ahead there is potential for growth and that we should at least be able to hold our own.

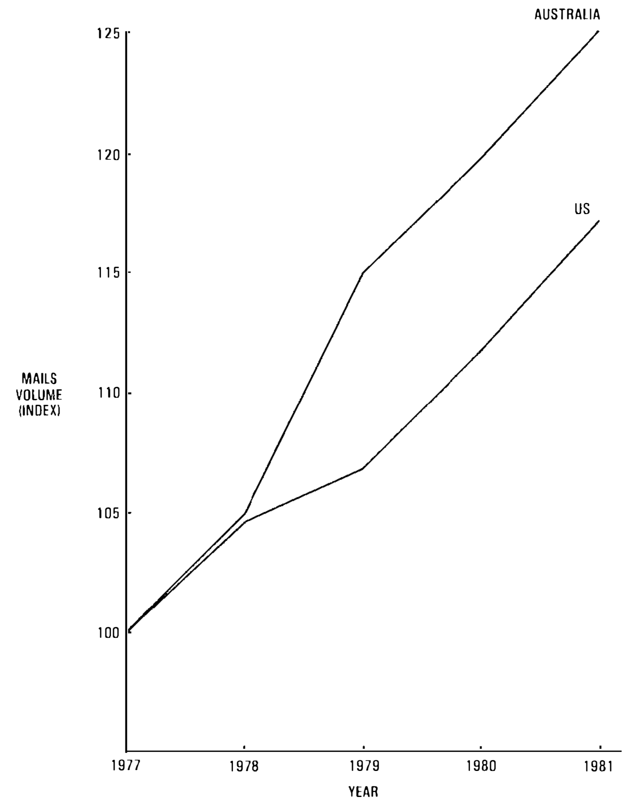
Our experience during the slump also points to the firmness of the postal business. On appointment to the PO Board 2½ years ago I set an immediate target of holding volume. We did lose a percentage point or two, but in the autumn of last year, through our efforts, the tide slowly began to turn and now, even though the economy is still showing no buoyancy, we have got mails volume on an upward track. In the first 6 months of this year it is about 2½% up on last year for the same period.

So research and current experience in circumstances of real adversity give a basis for looking to growth over the next 5 years. But you may ask, what of the impact of the telecommunications revolution in this period. Our research takes that into account. But this is where looking at experience overseas can help, because I think it is a fair comment that the application of telecommunications technology in the US is some way in advance of its adoption in this country. The volume of mail in the US has continued to grow by 2% to 3% a year every year for the last decade. It is still growing, and no one would claim that the American postal service, in spite of its many virtues, provides a high-quality postal service in terms of speed of delivery. In that sense we are well in advance of the US in our own postal service.

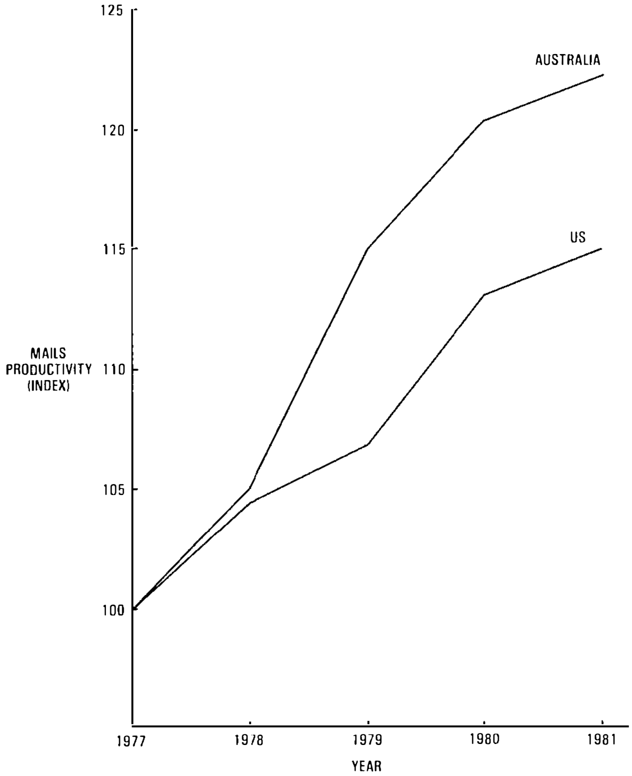
Now, one of the most significant aspects of growth is that it is self generating. The postal network has very high fixed costs and, roughly speaking, if in any year volume changes by 1%, the increase or decrease in unit cost is only ¼%. This means that if the growth engine begins to work for us, it starts to reduce our unit costs and that in turn makes us more competitive in the market place, which in turn of course helps to stimulate new growth. The significance of growth increases as we install mechanical letter handling equipment.

The Americans are not the only people who have benefitted from harnessing the engine of growth and new technology. The Australians have been able to work the same trick. I will show the only 2 slides I intend to use this evening—how volume and productivity has moved over the last decade in the United States and Australia (see Slide 1 and Slide 2).

Our strategy is to harness the engine of growth, and it is a great encouragement that notwithstanding the recession, which, as we all know, is the worst since the 1930s and hurting this country more than any other European country except Belgium, we have got our letter volume moving upwards. If you ask how we have done this, it is through honouring commitments to keep price increases within the rise in the cost of living, improving the quality of the mails service, adapting our service all the time to the needs of particular markets, and marketing these services with determination and real expertise. Those are all policies which will be continued, but they will be re-enforced by a programme to reduce unit costs and by a continuing commitment to keep our next price increase within the rise of the retail-price index (RPI).



SLIDE 1—Comparison of mails volume in the US and Australia



SLIDE 2—Comparison of mails productivity in the US and Australia

THE SECOND 5 YEARS

Could I turn now to the second 5-year period. What we shall achieve then depends upon the seeds being sown now. Such growth as we generate over the coming 5 years will give us momentum. But during this period we need to start the development and application of telecommunications technology to the mails service.

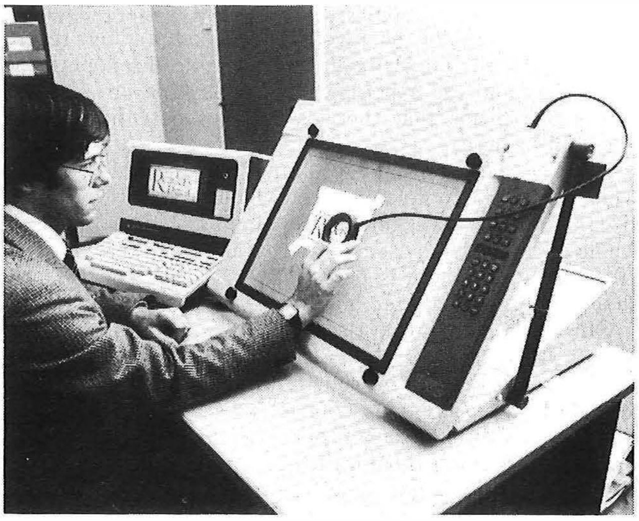
As I see it, when we talk of letters we talk of a means of communication. We are not concerned with how the information on a letter moves between the sender and the recipient and, if electronic transmission is the best vehicle, that is what we should be using. So far we have identified 2 particular segments of the market that lend themselves to the use of electronic transport of the message. The first is facsimile transmission, which we introduced on an international basis in the summer of 1980. So far, some 50 post offices have been equipped to deal with this traffic and we have just decided to proceed with a further 40. But we are still in the very early stages. What we are after providing is a bureau service for those users who, for a particular message or technical drawing, cannot themselves transmit directly from their own premises to the premises of the recipient. In short, we are after serving those who have not themselves got a transmitter and those who, while they have a transmitter, the recipient lacks a receiver.

While this would never, as I see it, be a mass market, it could be a significant one for specialised uses as well as for emergencies, providing that there is a substantial national and international network. At the moment neither is available. We therefore are taking a vigorous part—to some extent a leading part—in getting other postal authorities to join us in providing facsimile facilities. So far, progress has been slow, but it has been accelerating. Canada, the US, part of South America and the Netherlands are now linked in and we shortly expect to be joined at the international level by France and Germany. Then we shall be looking to the Far East and Australia for follow on. The US and Germany are crucially important because they are the biggest recipients of mail from the UK.

The other vehicle for electronic transmission concerns the mass market where we are concerned with postings normally numbered in thousands and hundreds of thousands. These are the mailings by large posters who, instead of printing and enveloping their mailings, will have the opportunity instead either to transmit the information electronically to PO computers or to send tapes. This information will be received electronically at the nearest post office, which will print and envelope the material so that the only leg work involved is that of local delivery.

With the US and Sweden, last year, we were the first postal authority to bring in a pilot-scale use of this technology when we set up stations in London and Manchester. Four further stations, Glasgow, Leeds, Birmingham and Bristol are to be established this year, and the consumer interest is very real.

INTELPOST, the Post Office facsimile transmission service



Digitising a customer's logo for electronic post—a computer-based service for mass mailings by wire

None of us can begin to judge at this stage how big is the potential of this form of electronic mail. The technology is already there. The only technological question is how far it can be developed in terms of colour printing and speed of processing. The main issue is the scale of product advantage given by the new technology, its cost advantage and, very significantly, customer acceptability.

These are 2 seeds for the second 5 years that we currently have at the nursery stage and which I hope will form a valuable part of our postal landscape in the mid- and late-1980s. But in this period my own view, and it is a strong one, is that conventional mail is likely to hold its own if we manage it well by vigorous marketing and by operating our conventional work more efficiently and providing we are able to realise the full advantages that will then be available to us from the mechanical and electronic handling of this conventional material.

LETTER MECHANISATION PROGRAMME

Can I therefore turn to a quick review of our letter mechanisation programme. As probably all of us here are aware, the policy of the postal business is to set up some 80 mechanised letter offices which will sort letters mechanically on the basis of the postcode. At the moment we have 51 such offices in operation and another 10 under construction.

As yet, the tangible benefits from this programme have been slight because they can only be realised when the system is close to completion and when, in particular, we have mechanised the main London offices. Partly because of the large capital costs involved and the scale of the operation, the big London offices are generally in the latter part of the programme.

It is disappointing to me that the whole programme has not been completed by now so that we are reaping the benefits. But there are some compensating factors from this limited rate of progress hitherto, namely that as we go along we are able to take advantage of advances in technology and learn the lessons of the past. Our engineers have served us very well in all this, and judged against the criterion of the optimum mix of engineering excellence in relation to costs, I think the PO stands in good comparison with the postal authorities of the world as a whole. The main challenge facing us is to make fully effective use of the equipment that has been installed, and here we have still a considerable way to go. Through realising the return that is there to be had from the machines, engineering will be able to make its full contribution to the later years of this decade.

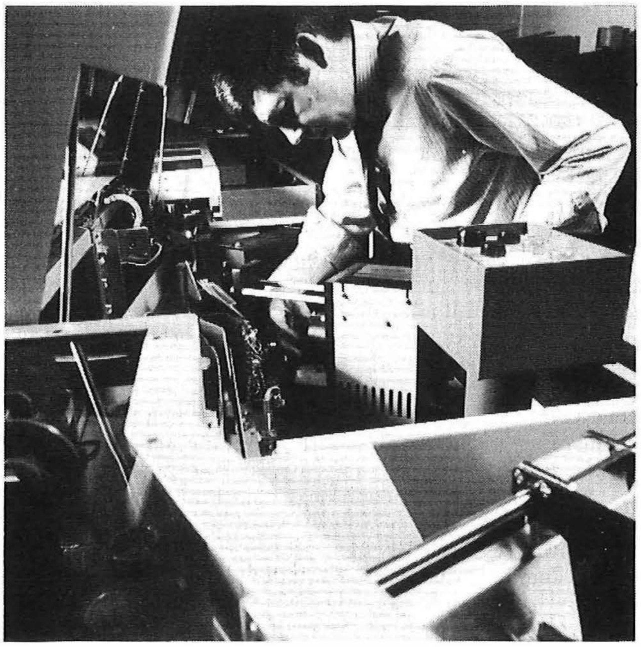
But, of course, we are already moving on from the first and second generations of mechanised letter sorting to the application of optical character recognition (OCR) to letter sorting. The first OCR machine in this country is to be installed in Mount Pleasant for development purposes before the end of the present financial year, and I look forward to it being adopted for operational purposes in our largest offices. Looking beyond that we are already engaged on more advanced letter sorting equipment to back up the OCR, and we believe what we have developed is in advance of anything elsewhere in the world.

So the second 5 years of my period is that in which the fruits of the work we are now doing on electronic transmission and the work over the last decade on conventional letter mechanisation will be realised, alongside the benefits that are coming from increasing the productivity of our conventional processes—3% last year and, I hope, another 3% this year.

PACKETS AND PARCELS

Conventionally, packets are treated as part of the letter mail and at 1000 million items a year they constitute a significant part—some 10%. But I think it is better to consider them with parcels since, in the main, we are dealing with material that is not in direct competition with telecommunications. This "movement-of-things" market has been one of continuing growth and a conventional wisdom is that it will continue to be so. Conventional wisdom is not always right, and one therefore has to look for the reasons for expecting growth.

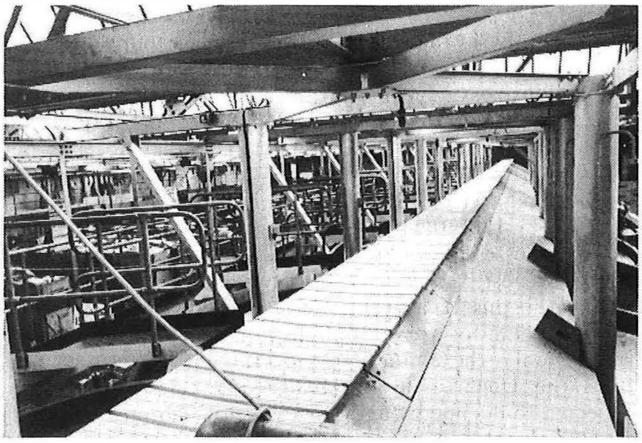
I would give pride of place here to the communications revolution because, instead of having to go to shops to seek goods and appraise them, we can to an increasing extent make the evaluation from hard copy or from information called up—or given to us whether we like it or not—on a television screen. Thus, as communications, in the broadest sense of that term, develops so also the potential for buying from home increases. Where buying does not take place from the home, I see it being increasingly so from bureaux; that is, places where information about goods, or samples of the goods are on view, but which are not places capable of providing the goods from stock. These will be provided increasingly from fulfilment houses.



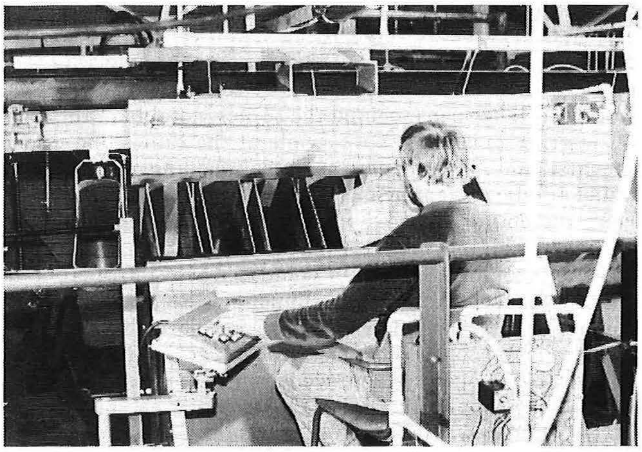
Optical character recognition equipment

The Royal Mail is a major competitor in the market place for the carriage of what is ordered from the home or from the bureau. In the mid-1970s, as some of you will recall, such were the losses on the PO's parcels business that the Board came close to a decision to shut it down. A loss of over £40M was being made on a turnover of some £70M. Since then, the parcels business has been turned round. The loss of traffic has been staunched and is now increasing. Last year there was an increase and in the first 6 months of this year there has been a further increase of 8%. Financially the parcels business is in good shape and is making a profit. When I talk of a profit, I am doing so on a fully allocated cost basis. The future of the PO in this market place depends on one factor—its ability to win business in the face of competitors. What has happened over the last 18 months gives the most tangible possible basis for confidence for the future.

The engineer is playing a full part in this policy of growth, and the large parcels offices are now highly mechanised. Parcel mechanisation is now the conventional business practice, but for packets this has not been so. From the engineering point of view, the development of an economically viable packet sorting machine has proved an obstinate and intractable problem. As I said earlier, we have 1000 million items that fall into the packet category and the development of a reliable and economic machine is therefore an important engineering priority. I am glad to acknowledge the work



Tilting-slat parcel sorting machine



Experimental packet sorting machine

that is going on in this country at the present time and the partnership that is taking place between the PO engineers and the private sector. We hope to have a prototype production machine in one of our offices next year.

The engineer is also helping us to develop our potential to handle larger size parcels than hitherto. Conventionally, we have concentrated on parcels of up to a weight of 10 kg. But commercially the customer is looking to us to handle all the parcels he produces, or if we do not do quite the whole range ourselves, to arrange for his whole business to be transacted. It is up to us to meet this commercial requirement and we are accordingly increasing our capability to handle the over 10 kg weight parcels. We are having the help here of the Cranfield Materials Handling Institute, and the first study showed that the mechanical solution offers not only financial savings but also quicker handling time.

There are developments ahead of us too in the handling of medium-sized parcels. We are currently planning a documented parcels service which could involve the inclusion of a bar code, which could be read either by hand-held units or scanners mounted on parcel sorting machines. This bar code could contain not only the address but, in addition, the information needed to enable us to control and monitor the progress of individual parcels. The technology for printing bar codes is well established and we should have the cooperation of the mail-order companies in using it. This, therefore, is an area which we are actively exploring with the support of our engineers.

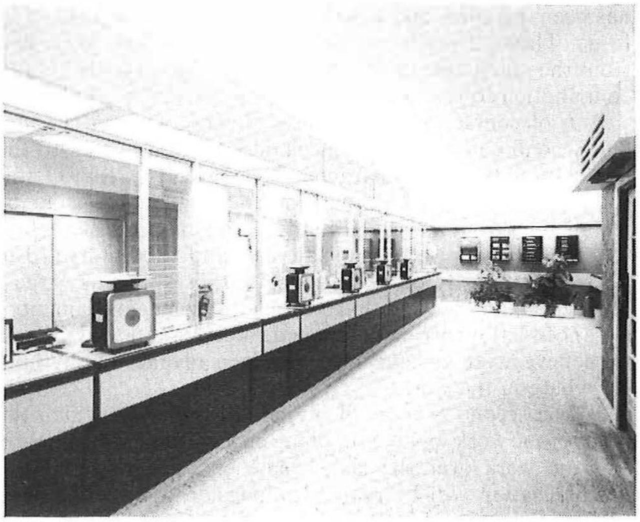
Our progress on the commercial and technical side therefore gives us optimism about our future for packets, and parcels large and small.

COUNTERS

Until relatively recently, Posts had been our overriding priority. It is, after all, and will continue to be, by far our biggest business. By any normal standards, the post-office counters, with a turnover of £500M a year, constitute a big business in their own right. Of course, when to the 1600 Crown offices we add over 20 000 sub-post offices, we have here the biggest network of shops in the country by a very big margin. I use the word "shops" consciously because that word expresses the Board's approach to these businesses.

We are positively seeking out new business. We have every need to do this because, with the changes the Government is introducing for greater options in payment of social security benefits, the amount of Government business coming from the Department of Health and Social Security is expected to decline by about 5% over the coming 4 years or so. Our objective is to win enough new business to cover this loss and to increase our business volume by about 4%.

This is where electronics and the electrical engineer comes in. To get the business, we need both to reduce our costs and to improve the kind of services we offer to customers. There is a lot we can do to streamline existing methods of working and make better use of existing facilities. But, if we can equip our counter clerks with a terminal through which he conducts his transactions, we can reduce a lot of clerical work that takes place behind the scenes, notably in the form of financial balancing work, while at the same time taking the first and fundamental step to providing on-line communication between the clerk and central data banks. In my view, the optimum course for us is for these terminals to be on-line in real time so that, where the need arises, the counter clerk can communicate with computer-held information at central points, which the customer needs, and which the counter clerk needs to transact business. This will be a major advantage to people who hold Girobank accounts, since they will be able to operate their account in a much more flexible way, at any counter throughout the country, than is possible at the moment. In principle, it would be possible for a customer to verify his balance at any post office and conduct transactions at any post office up to the limit of his account holding or credit limit. I think a development along these lines would be of considerable interest to holders of National Savings Bank accounts also.



A modern post office at Thetford

Experimental post-office-counter automation equipment

We also need to look at the possible case for installing automatic telling machines at post offices. These have not hitherto been a high priority, since our post offices are open during the full working day, Monday–Friday, and on Saturday mornings. This gives our customers a wide range of options as to time for conducting business but, since we are going down the mechanisation road and going into the possibility of on-line communication in real time, it makes sense for us to look very seriously at the case for at least some of our offices having automatic telling machines.

These are 2 main strands of thought, but there are, of course, other electromechanical devices which could be relevant to us, including automatic weighing and stamping of packets and parcels. We are entering into in-store video in the South West of England next month and, if that proves successful, as I hope it will, we shall be looking to extend that initiative nationally next year.

The demands that this potentially places upon us is great and rewarding both from the technical and business point of view. If our aspirations are realised in all the ventures we currently have under consideration, or even a high proportion of them, the post-office counters represent a very exciting business proposition with real potential for growth. But it is an opportunity that could cost us dear to forgo; we have, therefore, a double incentive to succeed in our technical aspirations.

GIROBANK

National Girobank is certainly a jewel in the crown of the PO. I mentioned it a few moments ago in the counters context, but it is of course a substantial business in its own right. After early struggles, Girobank is well established. It has years of profitable trading behind it coupled with a fast rate of growth. The bank is growing at a rate of between 15% and 20% a year. Last year it reached its first major milestone of a million current account customers and with the way we have been progressing this year, it will not be long before we notch up 1·2 million.

With this growth, the bank is branching out from its operational power house at Bootle to the establishment of regional centres, the first two of which, at Birmingham and Liverpool, we established early this year. Its range of services is expanding all the time and the bank will be entering into clearing next year.

With a return on capital on a current-cost accounting (CCA) basis of 16% and the rate of growth achieved in full competition with the larger private sector banks, Girobank is both a commercial business asset to the Corporation in its own right but an increasingly important generator of traffic for the mails and for the counter business of the PO.

THE ENGINEER IN THE PO

In this review of the 4 biggest businesses conducted by the PO, you will see that I have been able to talk with some confidence about our future prospects. This confidence is underpinned by last year's highly satisfactory profit—probably the highest ever made by the postal and Girobank side of the old Corporation—and a rise in productivity. The current rise in the volume of our business is very encouraging.

Within this framework, the engineer has a growing role as we take advantage of the new technologies in mails, counters and in banking. I was very glad that the first appointment of a regional director that fell to me as Chairman provided an opportunity to appoint one of our professional engineers. This reflects the extent to which operational and technical management are coming together.

While I have spoken so much about new developments, I want to recognise the dependence we have on engineers who are responsible for our vehicle fleet and for maintaining and pushing ahead with our new building programmes. This is a period of great renewal for the PO and as we renew we are looking for the best in terms of engineering services. I am glad to say we are getting it from our colleagues on the engineering side of the PO.

I said at the beginning of this talk that I earned a meagre living when I was employed as a forecaster. I will emphasise again that I, no more than anybody else, can foretell the future. But I can say with confidence that the opportunities are there for the postal business and with the help of the 8000 engineers in the business, I am confident that when this Institution has its centenary and my successor (for my long-term forecasting does not see me in the chair 24 years from now—the one certain prediction I make tonight) looks round the gathering of your successors, he will see with satisfaction a very large number of colleagues in your ranks from the PO.

Book Review

Microstrip Antenna: Theory and Design. J. R. James, P. S. Hall, and C. Wood. Peter Peregrinus Ltd. x+290pp. 184 ills. £26·50.

The geometry of microstrip devices makes them particularly difficult to analyse rigorously. As a result, this branch of microwave engineering relies heavily on empirical formulae and on results acquired during many years of field experience. Those studying microstrip antennas for the first time will find this book an excellent introduction to this complex subject. The experienced engineer will also find it an invaluable reference text, since it contains many useful results and a comprehensive set of references.

The subject of microstrip antennas cannot be adequately dealt with unless students understand the basic properties of microstrip lines and circuit elements. Therefore, the authors have devoted an entire chapter to these subjects. As a result the book is likely to be of interest to those seeking a basic understanding of microstrip-circuit design. The authors then proceed to consider radiation mechanisms in microstrip structures by the application of aperture-field methods. This leads to a detailed discussion of the design and analysis of patch antennas. From this basis the student is introduced to the more specific topics of linear arrays, circular polarisation, design limitations and practical manufacturing difficulties. The treatment of all these topics is extensive and well representative of the state of the art.

Recently developed mathematical models of microstrip antennas are presented, but only the principal steps in the arguments are given and the reader is left with an extensive list of references to complete his understanding. For those with a mathematical bias this section of the book would make a starting-point for the pursuit of interesting problems in microstrip-antenna analysis. Finally, the authors consider future developments and trends, and this section completes a generally excellent book.

M. J. MEHLER

TASI-E Circuit Multiplication Equipment

D. A. BARDOULEAU, C.ENG., M.I.E.R.E., and K. A. LAWTON, B.A.†

UDC 621.395.43: 621.315.28

Time assignment speech interpolation (TASI) equipment was first introduced in 1960. These early systems used analogue techniques, but modern circuit multiplication equipment using digital speech interpolation is now being introduced into service in the UK. This article describes the TASI-E system which is being installed to provide additional capacity on the submarine cable systems to North America.

INTRODUCTION

The first time assignment speech interpolation (TASI) equipment[1] to be brought into service in the UK was installed in Faraday international repeater station (IRS) in London in 1960. Its function was to increase the circuit capacity of the first transatlantic submarine telephone cable system, TAT1, in a cost effective manner. This it did by providing a nominal 72 trunks from 36 submarine cable channels.

A later development, TASI-B, was introduced in 1975 for use on the Pacific Ocean submarine cables between Australia, New Zealand and Canada. Further developments using microchip technology resulted in the TASI-C and TASI-D systems, but neither of these were marketed. The latest development is known as *TASI-E*. All these equipments were designed by Bell Laboratories and the production models were built by Western Electric Co. for the American Telephone and Telegraph Company (AT & T).

With the advent of high-speed digital switching, a number of equipments exploiting the principle of speech interpolation and using the generic title of *circuit multiplication equipments* (CMEs) have appeared on the market. In addition to TASI-E, they include such systems as COM 2, TLD and CELTIC. They have differing trunk/channel ratios and their merits fit them for use on particular types of circuits, for example, the public switched telephone network or private circuits. However, they all achieve the same basic objective of providing additional circuit capacity in a cost effective manner, which is why they are attractive to British Telecom International (BTI).

In November 1981, the first TASI-E terminal was installed at Stag Lane IRS, in North London, to work to another TASI-E terminal at Broadway exchange, in New York. This installation is the first of 10 TASI-E terminals, 3 of which are currently in service at Stag Lane IRS, providing additional circuit capacity on the heavily utilised submarine cable systems to North America. TASI channels may be routed via satellites or over submarine cables, but a mix of the 2 transmission media cannot be permitted for the channels from an individual TASI. This restriction is due to the need to keep to a minimum the relative delay between the inter-TASI-E terminal signalling channels and the traffic carrying channels.

The telephone traffic passed via the TASI-E systems is obtained from the De Havilland and the Mollison International Switching Centres (ISCs), both of which are situated within the Stag Lane complex. Later TASI-E installations to be located in Mondial House IRS will accept traffic from the Thames ISC.

SPEECH INTERPOLATION

CMEs, which seek to exploit the principle of speech interpolation[2], work on the principle that there is usually one talker and one listener at any instant in a given conversation. In a 4-wire telephone circuit this means that, on average, each direction of transmission is carrying speech for only approximately 50% of the time. Natural pauses in speech and in conversation reduce this percentage to 35–40% and, providing sufficient voice channels exist between the CME terminals, the circuit capacity of the system can be increased by a factor of up to 2·3:1, which is the maximum advantage that can be obtained by speech interpolation without clipping. This is achieved by interleaving bursts of conversation in a given direction with bursts from other conversations in the same direction by means of high-speed switching (Fig. 1). However, methods that make use of interpolation and coding changes to increase circuit capacity by up to 5:1 are currently being discussed. These methods are not, however, used in the TASI-E equipment.

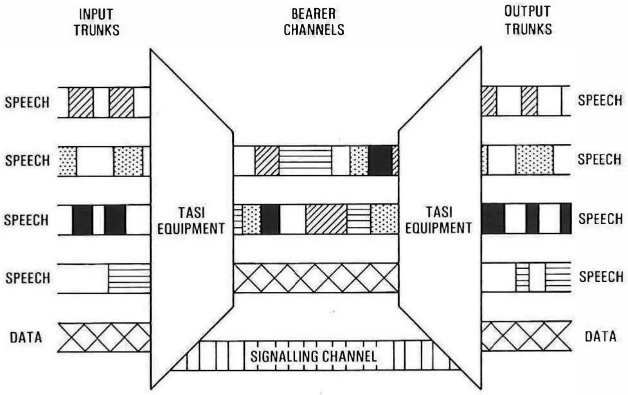


FIG. 1—Principle of interpolation

Modern CMEs give an improved quality of service to the customer because, whereas with the earlier equipments, the customer experienced the full effect of speech clipping, nowadays the fixed transmission delay offsets the effect of clipping. Thus, customers are unaware that their signals have been processed in any way.

TASI-E DESCRIPTION

The TASI-E CME was designed by Bell Laboratories and manufactured by Western Electric Co. for digital working on the 1·544 Mbit/s 24-channel pulse-code modulation (PCM) systems in widespread use within the USA. Analogue-to-digital (A/D) conversion equipment (known as *D4 channel banks*) has been provided so that the CME can be used in a wholly analogue environment. This is the manner in which it is being used in the UK. The TASI-E equipment, together with the A/D and D/A conversion equipment, are jointly known as the *TASI-E terminal*. The TASI-E terminal accepts 240 analogue speech circuit inputs (trunks) on the D4 channel bank equipment, where they are converted into a digital format. The resulting digital signals are input into the TASI-E equipment where they are processed and

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† Mr. Bardouleau is in the International Network Department and Mr. Lawton is in the International Operations Department, both in British Telecom International

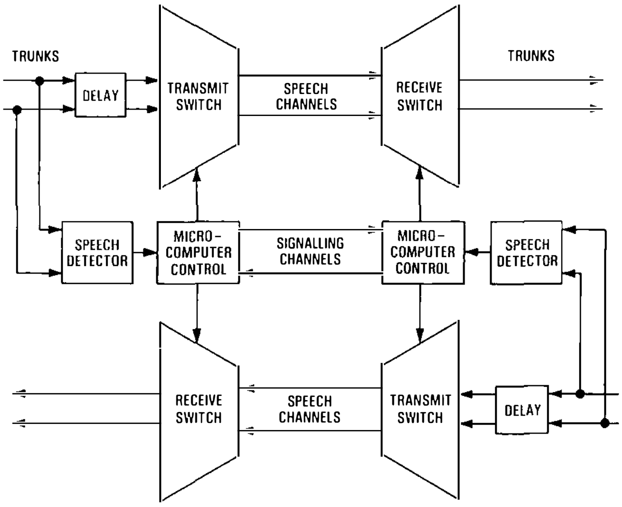

FIG. 2—Basic TASI structure

switched under the control of the transmit and receive microcomputers (Fig. 2). After processing and interpolation, the digital signals are converted back to an analogue format and transmitted over 120 channels of the transmission systems interconnecting the 2 TASI-E terminals. At the distant terminals, the reverse process takes place, with the additional option that the speech circuits may be extracted as either a digital stream based on the 1·544 Mbit/s 24-channel PCM format, a multiplexed analogue signal, or as 240 analogue circuits.

The 240 trunks are subdivided into 2 groups. One group of 120 trunks is designated *TASI and Through* and contains those trunks which in the event of a failure of the TASI-E equipment are bypass switched (restoration switched) around the TASI-E terminal by hard-wired physical paths.

The other 120 trunks are called *TASI ONLY* trunks and they are permanently busied for the duration of a restoration switch which automatically results from a major TASI-E fault condition.

OPERATION OF TASI-E

The major functional blocks of a TASI-E equipment are time-shared speech and tone detectors for signal detection; 2 microcomputers for control; transmit and receive time-slot interchanges (TSIs) for making trunk-to-channel connections; and signalling circuits for communications between TASI-E terminals[3]. Essentially, all the functions are realised by using digital circuit techniques with major functions carried out on a time-shared basis.

From the D4 channel banks, the signals enter the TASI equipment in a digital format as 10 digital streams (DS1s). (One D4 channel bank ≡ 48 channels ≡ 2 digroups ≡ 2 DS1s). The DS1 signals pass through restoration switching and maintenance access circuits before entering the digroup interface circuits (Fig. 3).

The maintenance access circuits allow access to each DS1 via front-panel jacks, and have provision for the extracting, inserting or monitoring of signals. The restoration circuits provide a means of connecting the first 5 trunk-side DS1s

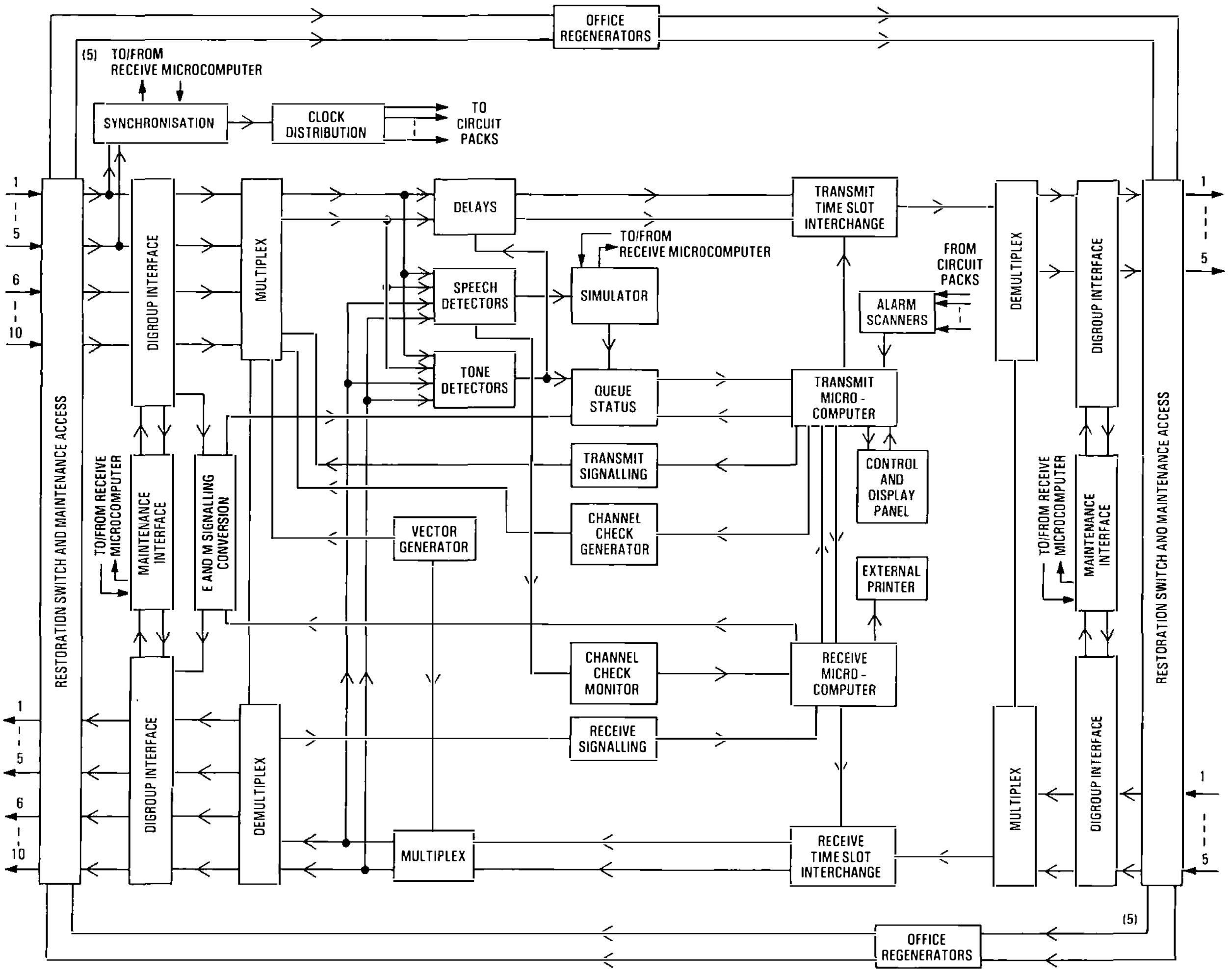

FIG. 3—Functional block diagram of TASI-E

directly to the channel-side DS1s in the event of a major TASI-E failure.

The digroup interface circuits perform line receive and transmit functions; that is, they regenerate and convert the DS1 signal from a bipolar to a unipolar format.

The next block of circuits consists of the multiplexers. The incoming DS1s are time-division multiplexed along with a number of internally generated signals to form 2 internal data busses for subsequent digital processing.

One bus contains the digital representation of the 120 TASI and Through circuits plus 8 maintenance and signalling signals, while the other contains the 120 TASI ONLY circuits plus 8 maintenance and signalling circuits. The 2 data busses utilise a parallel format (8 bits of data plus one bit parity = 1 byte, or word) and this information is carried a byte at a time on a time-shared basis. The information for the 128 trunks (120 externally originated, 8 internally generated) is formatted into a 128-time-slot frame. Time slots 1–120 carry message information from 5 DS1 signals. Time slots 121–127 and time slot 0 carry the maintenance and signalling information. The frame is repeated every 125 μs. For convenience, each of the data busses is referred to as a *DS120P* bus where the P stands for parallel. After the multiplexers, the signal path splits into 2 parts:

(*a*) a transmission path, and
(*b*) a detection path.

Transmission Path

The main signal flow through the TASI-E equipment is via the transmission path. This path includes the 50 ms delay circuits, and the TSI circuits which make the actual trunk-to-channel connections. The transmission path continues beyond the TSI to include the channel-side digroup interface, restoration switching and maintenance access circuits whose functions are the same as those for the trunk-side circuits.

The input to the transmit TSI is the 2 DS120P buses described earlier, while the output is one DS120P bus. This output bus carries 120 voice frequency channels, which are demultiplexed into 5 DS1s on the channel side of the TASI-E equipment.

Detection Path

The detection path includes speech detector; tone detector; queue status; and microcomputer circuits. These circuits are responsible for the detection of signals on incoming trunks and for the assignment of ACTIVE trunks to available channels.

Two sets of speech and tone detectors, operating on a time-shared basis, determine which trunks are currently ACTIVE. Each set operates on one DS120P bus. The outputs are processed by the queue status circuits, which form first-in/first-out connect and disconnect queues. The queues, which contain the lists of ACTIVE trunks in need of channels and INACTIVE trunks connected to channels, are interrogated by the transmit microcomputer to determine what new connections are needed.

The transmit microcomputer, after querying the queue status circuit, acts as the master; it determines the trunk-to-channel assignment, directs the transmit TSI to make this connection and sends the connection details to the far-end terminal via the inter-TASI-E terminal signalling channels. The transmit microcomputer also informs the queue status circuits of the new connection state for the affected trunks so that the connect and disconnect queues can be properly updated.

The receive microcomputer at the far-end terminal acts as the slave and, upon receipt of a new connection details via the signalling channel, directs the receive TSI accordingly. The receive TSI is the complement of the transmit TSI, in that it has 120 channels entering via one DS120P bus and 240 trunks leaving via 2 DS120P busses.

Inter-terminal signalling information to be sent to the far-end terminal is output from the transmit microcomputer to the transmit signalling circuits. The outputs of these circuits are time-division multiplexed with the incoming trunk DS1 signals as though they were trunks. These signals then enter the transmit TSI where, under microcomputer control, they can be connected to any outgoing channel. In this way, signalling-channel assignment can be flexible and, in the event of facility failure, alternative signalling paths can be established automatically.

Speech Detector

The speech detector defines the time periods on each trunk when a signal is present. The unit consists of the speech detector proper and a signalling bypass portion.

Speech Detection

To do its function properly, the speech detector proper needs to be able to distinguish speech, with its wide dynamic range, from noise and from the echo of far-end speech. To achieve this with the best possible grade of service for all talkers, and under a wide range of possible background noise values without causing excessive spurious activity indications, the detector takes into account the signal level of the speech and noise on the trunk currently being serviced.

The detector responds as soon as a single amplitude sample exceeds a *single sample* threshold or, if the level is too low for this, as soon as a filtered version of the signal exceeds an *exponentially mapped past* (EMP) threshold. EMP is a digital low-pass-filtering process. Both these thresholds are set adaptively as a function of speech and noise levels. Response time depends on the level of the signal spurt being analysed in relation to where past history has set the thresholds. The speech detector operates with echo protection, which prevents echo signals from requesting and getting service. The echo protection circuitry monitors both the transmit and receive transmission paths and declares the transmit signal to be an echo if its level is more than 6 dB below that of the receive signal.

To minimise the time taken to respond to signalling and to make sure that test tones get through, the EMP threshold always declares a trunk ACTIVE if its steady-state power exceeds −31 dBmO and the single sample threshold is always exceeded by any tone in excess of −17 dBmO. As a result, the speech detector responds within 0·25–1·5 ms for tones greater than −17 dBmO. For tones between −17 and −31 dBmO, the response time depends on the EMP circuit. For example, the response time of the speech detector to a −23 dBmO tone is about 14·4 ms. In general, the response time is a function of the 16 ms time constant of the EMP circuit and the encoding law of the signal.

Signalling Bypass

So that in-band signalling is subjected to minimal impairment, the speech detector circuitry has been augmented with a signalling bypass portion which detects the presence of moderate level multi-frequency (MF) tones and provides extended hangover (88 ms for tones −25 dBmO, 128 ms for tones −19 dBmO) to bridge inter-digit gaps. With this addition, MF addressing (signalling) can be passed through TASI as a single block. This signalling bypass portion of the speech detector is operated without echo protection, thereby allowing signalling tones in both directions simultaneously, a requirement of both the CCITT† No. 5[4,5] and CCITT No. 6[4,6,7] signalling systems.

The outputs of both the speech portion and the signalling

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† CCITT—International Telegraph and Telephone Consultative Committee

bypass portion of the detector are connected together via an OR gate to form a single output so that either portion can declare trunks ACTIVE and, therefore, in need of service. The speech detectors are time shared over 120 working trunks and there are 2 per TASI terminal. The outputs from the 2 speech detectors, together with the outputs from the 2 tone detectors, are passed to the queue status circuit.

Tone Detectors (Data Signal Recognition)

The tone detectors are designed to detect the presence of an *echo suppressor disabling* signal on a trunk. When this signal is detected, the tone detector provides an output to indicate that the trunk is ACTIVE and carrying data. This output is gated together with the single output from the speech detector, so that either detector can request service for a particular trunk.

The *trunk needs service* output from the tone detector is initiated with the detection of the *echo suppressor disabling* tone and remains in effect so long as there is significant energy in either the transmit or receive direction of transmission. The tone detector, like the speech detector, has access to both the transmit and receive paths. Because of this, an *echo suppressor disabling* tone transmitted in one direction will cause the near-end and the far-end tone detectors to operate and, therefore, a trunk to be assigned to a channel in both directions. This allows the TASI-E system to provide non-interpolated service for data sets sending the *echo suppressor disabling* tone and, thereafter, to monitor transmission in at least one direction.

The tone detector also has an output to the delay circuit which causes the 50 ms of one-way delay to be removed from the transmission path so long as the tone detector declares the trunk to be ACTIVE.

To ensure detection and initiation of a *trunk needs service* request, the *echo suppressor disabling* tone must be in the frequency band 1·94–2·25 kHz at a level of not less than −31 dBmO and must be present on the trunk for a minimum of 328 ms. After detection, the service request is maintained as long as the energy in either direction is in excess of −31 dBmO.

Additionally, a minimum 190 ms hangover is provided after energy in both the transmit and receive transmission paths has dropped below this level.

The tone detectors are time shared over 120 working trunks and there are 2 per TASI-E terminal.

In the event of the *echo suppressor disabling* tone not being detected, non-interpolated service is still given to a half-duplex data call. The constant energy of the data signal is detected by the speech detector and, therefore, once a trunk/channel association is established it is maintained until the energy level drops below a preset threshold level. However, the echo suppressor is not removed; nor is the 50 ms transmission path delay, since both these are controlled by the tone detector.

Queue Status

The queue status circuit preprocesses the activity information generated by the speech and tone detectors before passing it on to the microcomputers. The pre-processing consists basically of forming 2 queues: a connect queue and a disconnect queue. The connect queue contains trunks which are ACTIVE, but not connected to channels; these trunks need connections. The disconnect queue contains trunks which are INACTIVE, but connected to channels; these trunks are candidates to give up their connections to trunks that need them. The ACTIVE/INACTIVE state of each trunk is obtained from the speech and tone detectors once every frame (125 μ). The CONNECTED/DISCONNECTED status is obtained from the transmit microcomputer when new connections are made or when old connections are updated.

The queues are managed on a first-in /first-out basis with the queue status circuit storing the length of time each trunk is in the queue. Upon request, the transmit microcomputer is furnished with the identity of the trunks that have been in the respective queues the longest together with their status information.

The status information includes the background noise level on the trunk (used for noise matching); how long the trunk has been in queue (used for privacy and performance evaluation); whether the trunk is used for carrying data (used for traffic measurements); and activity, signalling-state, connection and queue-occupancy information (used for internal audits and performance monitoring).

Microcomputers

TASI-E uses 2 microcomputers which act as controllers for the terminal. They provide the control functions of examining the trunk and queue status information supplied by the speech and tone detectors via the queue status circuit, deciding which connections will be established, and of directing the transmit and receive TSIs to provide these connections. One microcomputer handles the transmit half of these functions and the other the receive half. In addition, the microcomputers control other internal operations such as channel check, fault detection and fault diagnosis as well as handling man–machine interactions via the control and display panel and printer. Each microcomputer is based on an Intel 8085 microprocessor and has a central processor unit, read-only memory, random-access memory (RAM), input/output and interrupt and select circuits. In addition, for communications between the 2 microcomputers in a TASI-terminal, the microcomputers are interconnected with a microprocessing circuit.

The software in each microcomputer is organised into an executive program for overall control; an interrupt-driven-program for setting up new connections; several time-shared programs to look after channel checks; maintenance and man–machine interactions; and an interrupt-driven clock program to provide timing functions.

TASI-E Signalling

TASI-E terminals communicate over the same transmission facilities that carry the interpolated speech signals. Each terminal is equipped with 6 signalling units to service up to 5 working channels and one spare.

The signalling channels carry trunk-to-channel assignments, signalling state, trunk noise levels, trunk-status information and information required for control and maintenance. Information is sent by transmitting one 32-bit signalling word every 6·67 ms. Each word is composed of four 8-bit bytes: 3 bytes for information and one byte for parity. In the case of a new connection, the 3 information bytes contain the trunk number, channel number and trunk status respectively. Trunk status consists of background noise information.

Transmission on the signalling channels is staggered so that a word is transmitted on channel 0, followed by a word on channel 1 and so on up to channel 5, with the spacing between transmissions equal to 1·11 ms (6·67 ms/6 channels). Each signalling word sent over one channel carries all the information needed to establish one new connection. As part of the signalling word, an 8-bit parity byte is transmitted. Parity is used for error detection only. If parity fails to check at the far-end, then the signalling word is ignored. To combat any loss of information caused by line errors, new connections are sent at least twice; once when the new connection is established, once shortly afterwards as a repeat connection and then, perhaps, later as part of a general update.

NEW CONNECTION PROCESS

The process by which ACTIVE trunks are connected to available channels is the most important function TASI-E per-

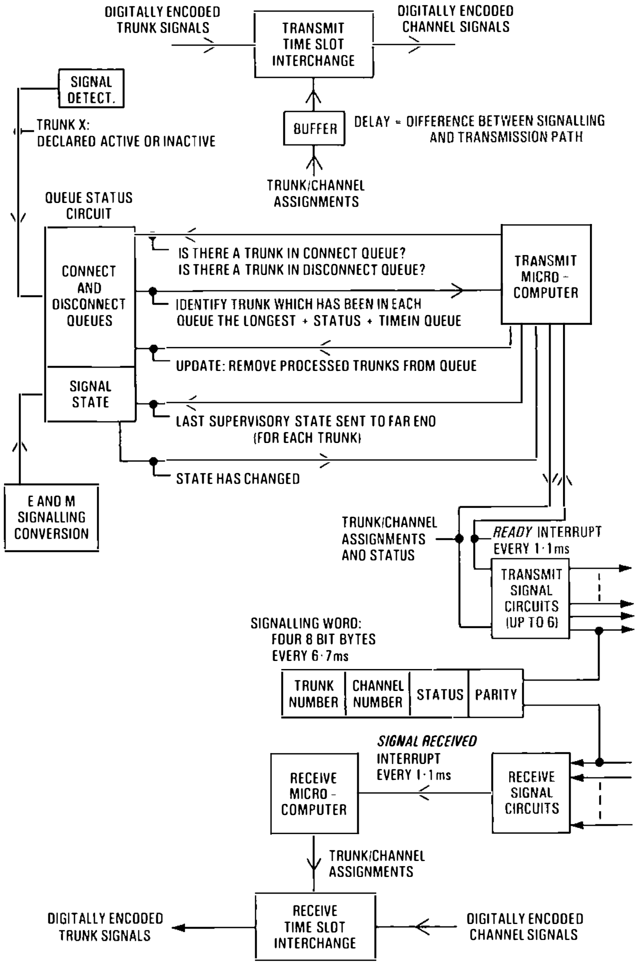

FIG. 4—The new connection process

forms. (See Fig. 4.) The process is initiated by the TASI-E signalling circuits, since a connection at the near-end cannot be set up until the same connection can be sent to the far-end. When a signalling circuit is about to complete the transmission of a signalling word and before it is ready to transmit the next word, it interrupts the transmit microcomputer to obtain the information it should send. Upon receipt of this interrupt, the microcomputer begins executing its transmit program. The transmit program has the following priority list of messages to be sent:

(*a*) high-priority command;
(*b*) new connection;
(*c*) supervisory state change
(*d*) disconnection;
(*e*) repeat connection; and
(*f*) trunk and channel updates.

At the top of the list are high priority commands such as commands to switch TASI-E IN or OUT OF SERVICE. If the transmit program finds no high-priority command to send, it queries the queue status circuit to see if a new connection or a supervisory state change needs to be sent.

To demonstrate the procedure assume that a new connection is needed and is possible; that is, there are trunks in both the connect and disconnect queues. The transmit program obtains from the queue status circuit the details of the trunk that has been in the connect queue the longest and the trunk from the disconnect queue that has been there the longest. Then, the program uses its internal tables to determine which channel is presently connected to the trunk taken from the disconnect queue. This channel, no longer needed by this INACTIVE trunk, is assigned to the trunk taken from the connect queue. This reassignment process takes several steps. Firstly, the program amends its internal tables to show that the trunk taken from the disconnect queue is now disconnected and that the channel it had is now connected to the trunk taken from the connect queue. Secondly, the program sends this information to the queue status circuit so that these trunks are removed from its queues. Thirdly, it informs the signalling circuit of the new connection to be sent to the far-end, and gives the trunk and channel number and the trunk status information. Lastly, the program sends the new connection information to the transmit TSI circuit where the actual connection is made.

This local connection information is not sent directly to the TSI, but is placed in a temporary buffer that will be read some time later. The reason for this delay is to synchronise the connections at the near-end and far-end of the system. The amount of delay introduced (approximately 20 ms) is equal to the differential delay of the signalling path, including delays in the data sets, relative to the delay in the transmission path.

The receive signalling circuits at the far-end, upon receipt of the complete signalling word, interrupt the receive microcomputer, which begins execution of its receive program. Here the program acts as a slave to the program at the transmit (near-end) of the system. The new connection information is read from the signalling circuits, the appropriate internal tables are updated, and the trunk and channel numbers are passed to the receive TSI where the actual connection is made.

This process for a new connection takes a finite length of time and would result in speech clipping occurring every time a new connection was made if it were not for the provision of a fixed delay in the transmission path. The *process clip* (caused by the transaction time of the new connection process), plus the statistically distributed *competitive clip* (caused by the finite probability that a message or signalling channel is not immediately available when required), minus the delay in the transmission path, gives the *total net clip* that a speech burst may suffer. The time required for a new connection is therefore an important factor in any impairment associated with TASI-E.

Table 1 gives sample figures for the transaction time of the component parts of the new connection process.

The detection time of 1 ms corresponds to that associated with a relatively high level such as would be associated with a signalling tone. The values shown for microcomputer processing and signalling circuit delay are typical values.

The combined effect of the process clip and the competitive clip is offset by 50 ms of one-way fixed delay in the trans-

TABLE 1
Typical TASI-E Transaction Delay Times

Transaction	Time (ms)
Process clip	
Detection	1
Microcomputer processing	1
Signalling circuit delay	1·67
Signalling word length	6·67
Data set delay	13
Total	23·34
Competitive Clip	27
Total	50·34
Fixed delay	−50
Perceived clip	0·34

mission path. The fixed delay is realised by the use of dynamic RAMs—RAMs operated in a fashion that mimics a long shift register. The delay can be removed for each of the 240 trunks individually—a feature provided to remove delay from trunks when they are carrying data traffic.

TRANSMISSION OF SUPERVISION AND ADDRESSING INFORMATION

TASI-E has been designed to be compatible with CCITT No. 5 and CCITT No. 6 signalling systems.

The CCITT No. 5 system uses compelled signalling and the TASI-E speech detector has been augmented with a signalling bypass circuit that permits the transmitting of signalling tones in both directions simultaneously. Furthermore, the signalling bypass circuit provides sufficient hangover so that MF addressing tones following a seizing tone are passed through TASI-E without being subject to clip.

The CCITT No. 6 system uses a common link for signalling that is not routed through TASI-E and so remains unaffected. However, associated with this signalling system is a continuity check of the transmission path. This check consists of a signal that is transmitted to the far-end switch and looped back; therefore, it passes through TASI-E in both directions simultaneously. Again, the signalling bypass circuit in the speech detector allows for this type of transmission.

DYNAMIC LOAD CONTROL

Conditions such as an unusually high percentage of data traffic or the loss of some of the channels that normally carry interpolated traffic could lead to excessive clipping. To deal with this situation, the queue status circuit has been augmented so that it can provide the transmit microcomputer with competitive clip measurements. If 7 or more new connections have clipping greater than 50 ms, a test is considered a bad test, if 4 consecutive bad tests are encountered then the microcomputer activates a control lead associated with the TASI-E equipment. The control lead is connected via the supervisory system to the international switching unit (ISU).

This enables all new calls to be blocked until the number of calls being carried decreases to the point where clipping becomes acceptable. At this point, the control lead indicator is released automatically. This process is known as *dynamic load Control* (DLC).

CHANNEL CHECK, GAIN CORRECTION, NOISE MATCHING

To minimise any degradation in service that may be introduced by TASI-E, the differences between the channels used at various times during a conversation must be kept to a minimum. It is also imperative that a bad channel is not allowed to impair a large number of connections by being switched from one to another.

The TASI-E equipment automatically measures the transmission performance of all channels. They are measured sequentially, each channel being measured when the trunk connected to it is INACTIVE. The channel check measurement consists of a single-frequency gain measurement, a noise measurement and a delay measurement.

If the gain measurement indicates that a channel is within 2 dB of the expected loss, then no action is taken. If the loss is within 2 to 4 dB, a 2 dB correction is introduced at the receiving end.

If the loss is more than 4 dB from its expected value, the channel is removed from TASI service by locking it to its corresponding TASI and Through trunk. (This is known as a *channel lock*. Its purpose is to allow maintenance to take place on the non-interpolated channel without the remaining interpolated channels being affected.) The channel gain corrections are made in the receiving TSI. This feature of channel gain correction ensures that the subjective degradation of a circuit resulting from it being switched from a channel with a given loss to another channel with a different loss is minimised.

The channel check noise measurement is used, in a manner similar to the gain measurement, to remove a channel from TASI service if it is excessively noisy. Additionally, the noise measurement of the channel made by channel check is combined with the noise measurement of the trunk made by the speech detector at the transmitting end, to provide a feature called *noise matching*. When a listener is disconnected from a channel, a difference in the background noise level is perceived if corrective steps are not taken. With noise matching, TASI-E computes the total background noise by adding the trunk noise to the channel noise and inserts this noise into the listening path at the time of disconnection.

TASI-E SUPERVISORY SYSTEM

To interface the TASI-E terminal in the UK with the national network, BTI have designed a comprehensive supervisory system[8] which ensures that, under conditions of DLC, system failure and removal for maintenance, the correct actions are taken automatically so as to cause the minimum disturbances to either new or existing calls.

The system controls the TASI-E circuits from up to 5 ISCs and is configured as shown in Fig. 5. The main features of the system are:

(*a*) A control unit that provides an interface for the alarms and control conditions from the TASI-E terminal and controls the distribution of signals to the various ISCs. This unit is situated close to the TASI-E terminal and provides both a local and remote display of the alarms, the signals and their acknowledgements. It enables a rapid diagnosis to be made of any failure to apply the necessary conditions to the TASI circuits at the ISC.

(*b*) An interface relay-set at each ISC to receive the signals and return acknowledgements to the control unit. This relay-set applies the necessary conditions to the TASI-E circuit terminations at the ISC, supplies a display of conditions applied (for the maintenance staff) and allows some conditions to be applied manually in the event of failure of a link from the control unit.

(*c*) Links between the control unit and the interface relay-set. These links fall into 2 categories: those for use within DC working limits and those for long-distance application using a telemetry system.

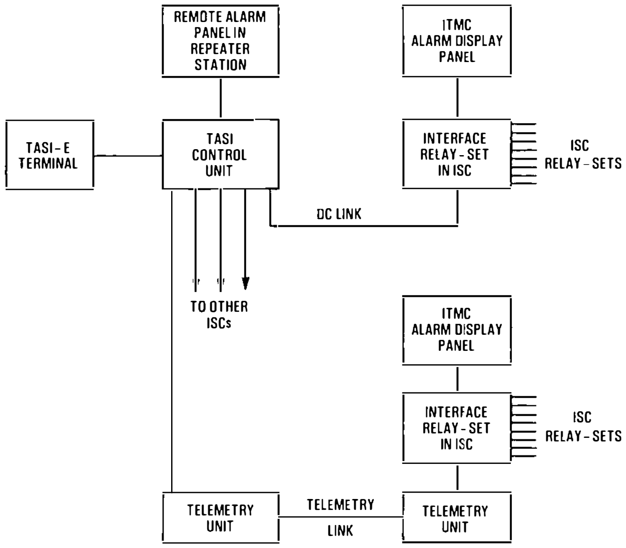

FIG. 5—BTI TASI-E supervising system

For ISCs collocated in the same complex as the TASI-E terminal, a trunk processing lead is provided from the A/D conversion equipment to the TASI circuit termination for each TASI-E trunk. This blocks traffic from that circuit in the event of a failure of one of the D4 channel banks for the duration of the fault.

MAINTENANCE OF THE TASI-E SYSTEM

The TASI-E equipment is provided with a number of internal programs that are run automatically in response to TASI-E alarm conditions. Fault location down to printed-wiring board (PWB) level is indicated by a diagnostic number displayed on the TASI-E equipment and, by reference to published data, the faulty board can be identified and changed. In some cases, however, several alternative boards are indicated and faulting is based on elimination.

At the beginning of each maintenance cycle (about every 30 s), the maintenance system thoroughly checks itself. Tests begin at the microprocessors and the power supplies that power the maintenance circuitry and continue all the way through to the remote alarm circuits on individual PWBs. If possible, a fault is actually simulated on the individual PWBs to perform this test. If service is affected by a fault simulation being caused, the remote alarm circuit on the PWB sends a special alarm indication and the microprocessor verifies receipt of the indication. This test of maintenance circuitry occurs about every 20 scans of the alarm scan points. However, even with the sophisticated self-diagnostic facility that is becoming commonplace on new digital equipment, there still remains a need to interpret the diagnostic readouts correctly in order to restore the equipment to service with a minimum of delay. The TASI-E system continuously monitors the channels between the TASI-E terminals by checking:

(*a*) the gain, for which variations of up to 4 dB can be corrected automatically,

(*b*) the noise level for excessive noise on the channel, and

(*c*) the delay on each channel.

A failed channel is removed from use by the system until further measurements indicate that it can be restored to service.

PERFORMANCE

To assess the performance of a TASI-E system for maintenance or service reasons, use is made of external programs. The operational syntax for these programs is given in published TASI-E literature and the programming and assessment of the printouts is done by IRS maintenance staff. Two such programs which vary the presentation of what is basically the same information, but assessed over different time periods, are the 15-minute reports. The first of these gives service information over the past 15 minute period. The second gives the same information for the worst 15 minute period and starts from a predetermined time when the memory was last cleared. For the UK terminals this is 08.00 hours each morning. Fig. 6 gives a typical report output from which it can be seen that a great deal of useful information is given, including the number of channels operational, the number of data calls being carried, and the average channel activity, all of which is useful information to the maintenance engineer who needs to know the current status of the equipment. Nineteen external programs are available and they cover all aspects of TASI-E maintenance.

As the TASI-E equipment installed at Stag Lane was the first operational TASI-E to come from the USA, it was inevitable that some teething troubles would be experienced. Some of these, in particular problems with integrated circuit connectors and certain software problems that were service affecting, owed their solution to a large extent to the efforts of BTI maintenance staff. AT&T have recorded their appreciation of the efforts of BTI maintenance staff in helping to resolve these difficulties. The equipment is now functioning reliably and the fault rate is dropping steadily towards the manufacturer's estimate of 3·5 faults/terminal/year. Arrangements have been made for the inclusion in the annual training program of suitable training courses, and plans are well advanced for the provision of an on-site repair centre for faulty TASI-E PWBs and D4 channel banks.

```
M 45 REPORT :TASI 00106, STATISTICS, DATE 10/05/85, TIME 16:45:33,
           CLIQUE NUMBER                 1,
           CLIQUE OUT (S)                0,
           TRUNKS                     0240,
           CHANNELS                   0118,
           AVE ACTIVE TRUNKS       .805E+2,
           AVE ACTIVITY            .335E+0,
           AVE DATA TRUNKS         .500E+1,
           AVE CQ TRUNKS           .131E+0,
           AVE (DQ+PQ) CHANNELS    .339E+2,
           AVE MQ TRUNKS           .000E+3,
           MIN TRUNK LOCKS            0,
           MAX TRUNK LOCKS            0,
           MIN CHANNEL LOCKS          0,
           MAX CHANNEL LOCKS          0,
           MIN TRUNK-CHANNEL LOCKS    0,
           MAX TRUNK-CHANNEL LOCKS    0,
           MIN CHANNEL-FAILURE        0,
           MAX CHANNEL-FAILURE        0,
           TOTAL NEW CONNECTS    .49258000E+5,
           SAMPLES TAKEN           941,
           DLC TRANSACTIONS          0,
           DLC ON TIME               0,
           CLIPS (MS)  CQ(MS)    FRACTION
             -          >0       .100E+1,
            >0          >24      .365E-3,
            >10         >34      .365E-3,
            >25         >49      .305E-3,
            >50         >74      .203E-3,
            >75         >99      .142E-3,
            >100        >124     .406E-4,
            >150        >174     .000E+3
```

FIG. 6—Typical 15-minute current report

Finally, mention should be made of a recent refinement to the installation that has been brought about by the increasing number of TASI-E terminals at Stag Lane. The diagnostic facility on the TASI-E equipment requires the use of a suitable printer on which to output information. The provision of one printer per TASI-E terminal was considered to be extravagant, an unwarranted maintenance hazard, and an unnecessary use of scarce accommodation. A search for a suitable multiplexing device was therefore initiated. One was finally found and it is now planned that for installations of up to 10 assorted CMEs, their outputs will be fed into the multiplexer and stored and released, one complete message at a time, on to a standard Transtel printer. This refinement proves to be cost effective when more than 4 CMEs are to be installed in one location.

ACKNOWLEDGEMENTS

The authors wish to thank colleagues in BTI who assisted in the preparation of this article. They also thank AT&T for permission to refer to TASI-E documentation.

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New Television Distribution Network for Channel 4

BRITISH TELECOM PRESS NOTICE

In August last year, British Telecom (BT) completed on schedule a new nationwide distribution network worth more than £7·5M for Britain's new TV service—Channel 4, and Sianel 4 Cymru, in Wales. The planning and installation of the new network was Britain's single largest TV project and was completed in just under 3 years from when the Independent Broadcasting Authority (IBA) and the programme companies placed the order. This achievement gave the new services a unique start—when the new channels started broadcasting programmes in early November they were available to about 87% of the UK's population. The new services were not available in certain areas because some of the IBA's planned relay TV stations had not been installed. In contrast, the earlier networks for BBC1, BBC2 and ITV were first installed in London and then extended to the rest of the country over several years.

At a ceremony held at the London Telecom Tower in September to mark the formal handover of the network to the IBA, Sir George Jefferson, Chairman of BT, said: "BT's engineers had just under 3 years to plan, specify, install and commission the new network. It is a tribute to their efforts, and to our contractors, that we completed the network, on schedule, this August. It was done by good management and by demanding much shorter than usual delivery times."

In addition to the expected problems presented by a major engineering project, BT had to contend with extra difficulties created by the atrocious weather experienced during winter 1981. Heavy snowfalls cut off some of BT's microwave stations for weeks and delayed cable laying. Despite this, the project was still completed on time.

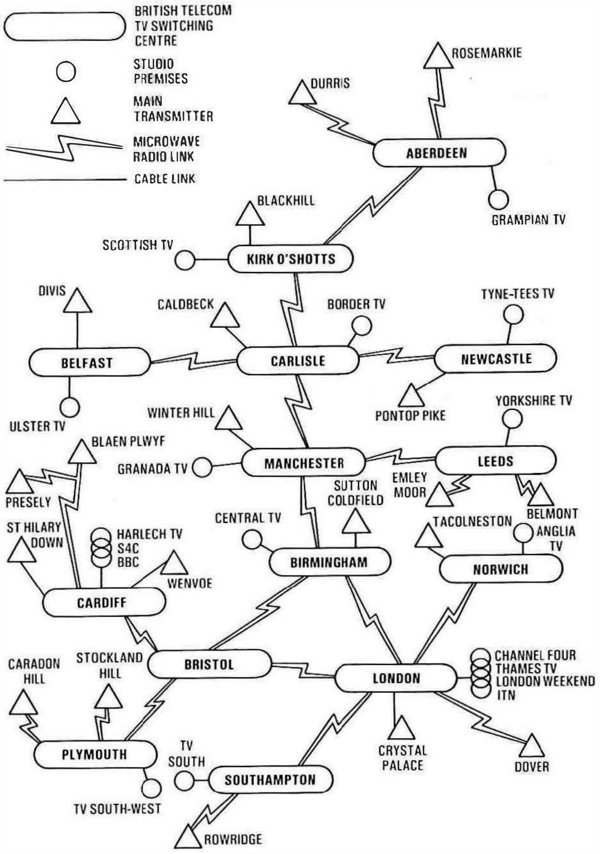


FIG. 1—Distribution network for Channel 4

FIG. 2—Adjustments being made to one of the new dish aerials mounted on the London Telecom Tower

The new distribution network (see Fig. 1) links the 2 new companies' studios with 15 of Independent Television's existing studios and with 19 of the IBA's main transmitters. The main part of the network consists of new long-haul microwave links on 23 routes spanning the country between 56 of BT's microwave stations. These links were provided by the General Electric Company (GEC), Coventry, at a cost of £5M, and involved the installation by BT of new dish aerials at the radio stations (see Fig. 2). Most of the links operate in the upper 6 GHz band and use GEC's new slimline equipment practice systems.

The local lines between microwave stations, studios and the IBA's transmitters are provided on high-grade 2·6/9·5 mm coaxial cable. A total of 130 km of the new cable, supplied by Pirelli General in Southampton and Telephone Cables in Dagenham at a cost of £2·5M, was used to provide 40 separate links in the system.

In addition, numerous smaller contracts were placed for specialised video transmission equipment designed by BT.

The success of this project clearly demonstrates the huge reservoir of highly professional expertise in all aspects of TV distribution that BT has now built up, and underlines the close link that has long existed between BT and the country's television broadcasting organisations.

Modem 36—A New Modem for 48–72 kbit/s Data Transmission

D. W. PARKINSON, B.SC., and I. B. HARVIE†

UDC 621.394.4: 681.327.8

The operation and performance of a new modem for data transmission at a number of fixed rates between 48 and 72 kbits/s over group-band links in the frequency-division multiplex network is presented. This modem, designated the Modem 36, was designed in the British Telecom Research Laboratories to a specification based on CCITT Recommendation V36; it includes an adaptive equaliser, which gives powerful correction properties and considerably simplifies existing planning rules. The Modem 36 supersedes the Modem 9 and will normally be used with the Modem 35.*

INTRODUCTION

A new group-band modem, to replace the Modem 9, has been designed at the British Telecom Research Laboratories to a specification based on CCITT* Recommendation V36[1]. The modem is designated the *Modem 36* and can operate at 48, 56, 60, 64 or 72 kbit/s over group-band links in the frequency-division multiplex (FDM) network. The transmission method uses lower-sideband, vestigial-sideband amplitude modulation on a 100 kHz carrier, combined with spectrum shaping using an encoding technique known as *1, 0, −1 multiple response*; an adaptive equaliser is also included and this enables the modem to operate over any group-band link, including those using edge groups of a supergroup, without the need to use delay-equalised through-group filters or any special planning restriction.

The Modem 36 has been shown to give a very satisfactory performance in the laboratory and also when tested on actual group-band links.

The Modem 36 is normally sited in a repeater station, and transmission between it and the customer is provided by Datel Modem 35, using the WAL2 technique for transmission over physical pairs[2]. The Modem 36 incorporates a Modem 35 module to interface to the physical pairs (Fig. 1).

HISTORY

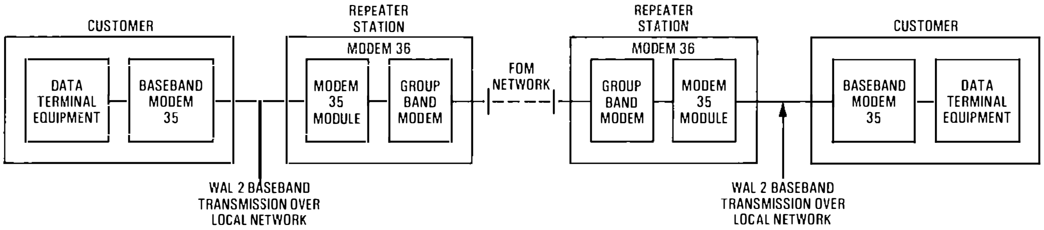
At present, group-band data transmission links are provided by British Telecom using the Modem 9[3], which operates in conjunction with the Modem 8 according to CCITT Recommendation V35[4]. Briefly, the Modem 8 provides the customer interface, a timing signal if required, and baseband transmission via physical pairs to the Modem 9, which is located at the nearest point that gives access to the FDM network. The Modem 9 receives these signals and retransmits them via a group-band channel (60–108 kHz), using vestigial-sideband amplitude-modulation on the lower sideband of a carrier at 100 kHz. The Modem 9 receiver at the remote-end demodulates the group-band signal, and transmits it at baseband to the receiving Modem 8 where timing-signal recovery and regeneration are performed. Thus, the Modem 9 functions as a frequency changer and can operate with binary signals at rates up to a maximum of about 48 kbit/s. The spectrum of the transmitted signal is sensibly uniform over much of the group-band and the transmission method is rather sensitive to the band-edge group-delay distortion that arises in group-band channels. Because of this, all through-group filters on a link used for data transmission must be equalised and edge groups in a supergroup cannot be used.

The Modems 8 and 9 are unable easily to provide a higher rate of transmission than 48 kbit/s. Also, many components used in the original designs are now obsolescent, and difficult and expensive to obtain. For these reasons, it was decided to produce a new design based on CCITT recommendation V36 to provide the higher data rates, and to remove as many of the planning restrictions as possible.

CCITT RECOMMENDATION V36

CCITT Recommendation V36[1] relates only to transmission over a group-band channel, and provides for a modem that operates synchronously at a number of fixed rates between 48 and 72 kbit/s. Lower-sideband vestigial-sideband amplitude modulation on a carrier at 100 kHz is used, as in earlier Recommendations. However this is combined with a 1, 0, −1 multiple-response technique (often known as *partial-response, class 4*)[5] to shape the signal spectrum so that most of the power lies near the centre of the channel and little lies near the band-edges. (Fig. 2). Thus, this transmission method is relatively insensitive to the group-delay distortion introduced by the through-group filters (also shown in Fig. 2).

The response shown in Fig. 3 is the output signal from a 1, 0, −1 multiple-response system excited by a single input pulse. The multiple-response process produces a 3-level output signal from a 2-level (binary) input signal. This means that a multiple-response system has a poorer signal-to-noise



FDM: Frequency-division multiplex

FIG. 1—Application of the Modem 36

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† Research Department, British Telecom Headquarters

* CCITT—International Telegraph and Telephone Consultative Committee

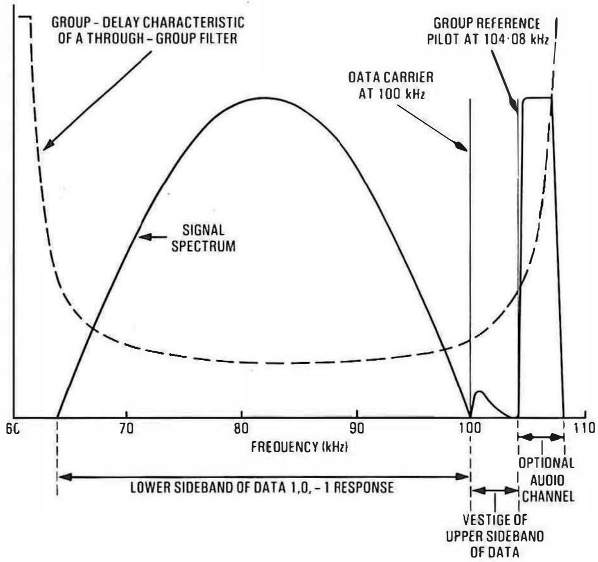


FIG. 2—Group-band frequency spectrum

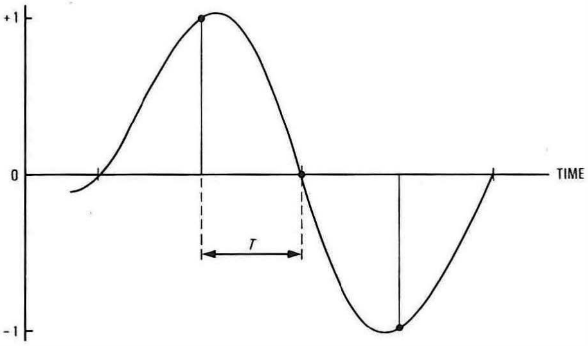


FIG. 3—Impulse response of 1, 0, −1 multiple-response process

ratio than a 2-level system with the same signal amplitude, but this disadvantage is more than offset in practice by the improved tolerance to group-delay distortion. With optimum adjustments of demodulating carrier phase and sampling instant in the receiver, a basic V36 modem will operate satisfactorily at 64 kbit/s through one unequalised through-group filter.

As shown in Fig. 2, the spectrum has a null at the carrier frequency and this makes the insertion of the carrier pilot simple. A group reference pilot of 104·08 kHz can be added to the signal and also, if required, an audio channel occupying the band 104–108 kHz.

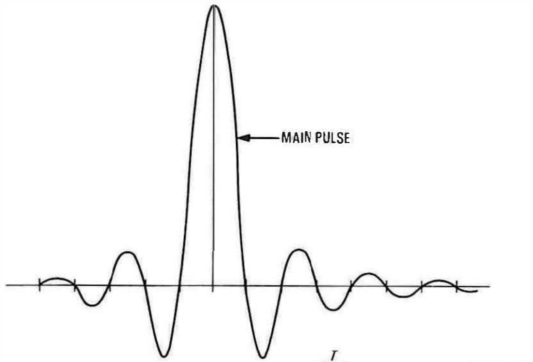


FIG. 4—Band-limited pulse with no distortion

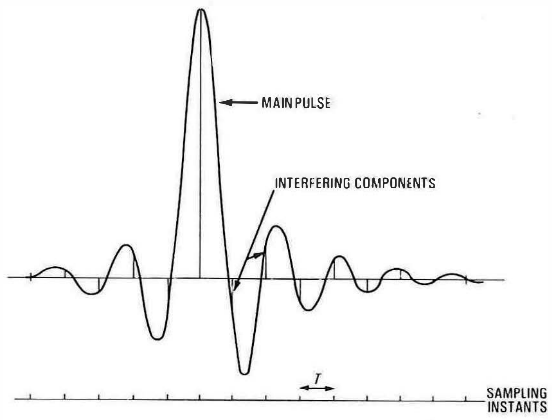


FIG. 5—Band-limited pulse with group-delay distortion

ADVANTAGES OF ADAPTIVE EQUALISATION

A data pulse, transmitted over an ideal band-limited channel, is illustrated in Fig. 4, which shows that the instantaneous response is zero at the sampling instants, *T*, either side of the main pulse.

Group-band links in the national FDM network may include up to 3 through-group filters. A data pulse transmitted over such a link suffers waveform distortion caused primarily by the group-delay distortion of the through-group filters. This waveform distortion spreads out in time the response of a data pulse such that it overlaps, and interferes with, adjacent pulses in a digital wavetrain (Fig. 5). This effect is called *inter-symbol interference* and it reduces the margin against noise in the receiver; in severe cases, it can cause systematic decision errors.

The Modem 36 includes an adaptive equaliser, which automatically corrects this distortion and so avoids the need for individual group-delay equalisation of all the through-group filters in the communications link. The adaptive equaliser includes an analogue delay line, which holds successive data pulses exactly as they are received. The received signal, from which the data is recovered, is taken from the centre of the delay line. By means of pre- and post-taps on the delay line, adaptive networks add or subtract proportions of the earlier and later data pulses in such a way as to reduce the inter-symbol interference arising from these adjacent pulses.

DESCRIPTION OF THE MODEM 36

Mechanical Design

The Modem 36, complete with its power supply, occupies a single 62-type equipment practice shelf (Fig. 6) and includes a Modem 35 baseband extender. The Modem 36 transmitter consists of 2 cards, and the receiver of 5 cards; an additional card is used for transmitter and receiver interfaces. There is also provision, if required, for a standard speech channel card, corresponding to channel 1 of a standard 12-channel telephony group.

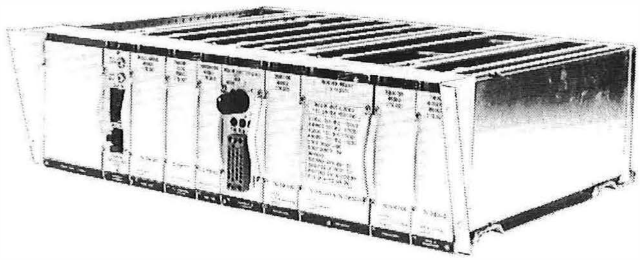


FIG. 6—Modem 36

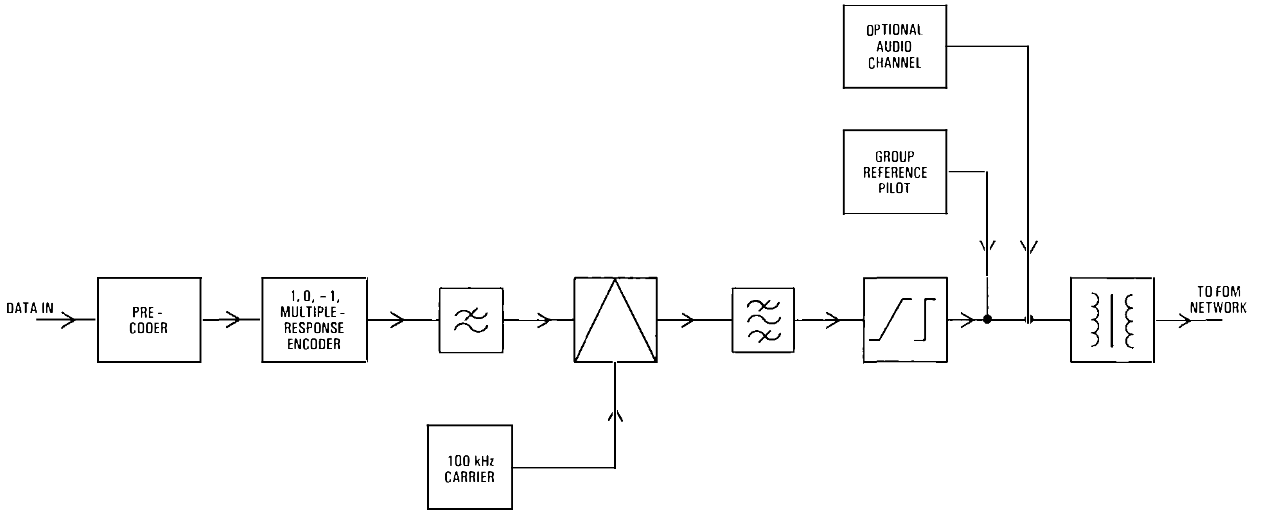


FIG. 7—Block diagram of the Modem 36 transmitter

The Transmitter

The transmitter consists of a transmitter card and a transmit channel filter card, and is shown in block diagram form in Fig. 7. The transmitter requires a timing signal, binary baseband data and *request-to-send (RTS)* signals from the Modem 35 receiver. Data can be transmitted at 48, 56, 60, 64 and 72 kbit/s.

The Modem 36 is capable of operating in 2 separate modes, selected by straps: the switched-carrier mode; and the constant-carrier mode.

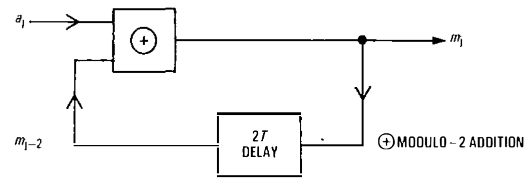
(*a*) In the switched-carrier mode, the *RTS* signal is used to control the carrier, which inhibits or enables the transmission of signals over the group-band link.

(*b*) When operating in the constant-carrier mode, a modulated signal is always transmitted over the group-band link, which enables the Modem 36 receiver to maintain correct timing and carrier phases even when the customer's Modem 35 is switched off.

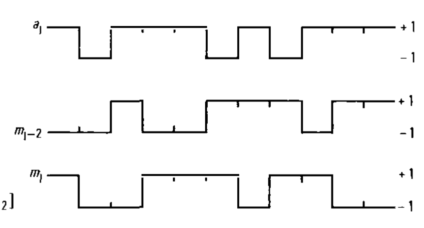
The requirements of the constant-carrier mode are achieved in the following manner. When the *RTS* signal is ON, the Modem 36 transmits directly the data presented to it. In normal operation, this would be the customer data that has been scrambled by a V35 scrambler within the Modem 35. In the absence of data, signalled by the *RTS* signal being in the OFF state, the Modem 36 transmitter transmits an internally-generated pattern of binary ones, scrambled according to CCITT Recommendation V29[6]. The Modem 36 receiver recognises this pattern and turns off the received line signal detector, so preventing the transmission of unwanted data to the remote terminal equipment.

To simplify the decoding process in the receiver, the data to be transmitted is pre-coded. The pre-coding ensures that the outer levels of the transmitted 3-level signal correspond to a binary one and the centre level corresponds to a binary zero. The circuit used is simple, as shown in Fig. 8(*a*), and Fig. 8(*b*) shows the timing diagrams for the pre-coding process, in which a_j is the input data and m_j is the pre-coded data.

The pre-coded binary data, m_j, is translated in the time domain into a 1, 0, −1 multiple-response 3-level signal[5], using the simple circuit shown in Fig. 9(*a*). It can be seen from the timing diagrams in Fig. 9(*b*) that, by delaying the binary data, m_j, by 2 data unit intervals ($2T$) and subtracting the resulting data, m_{j-2}, from the original binary data m_j, the output sequence, c_j, is a 3-level signal. Comparison of

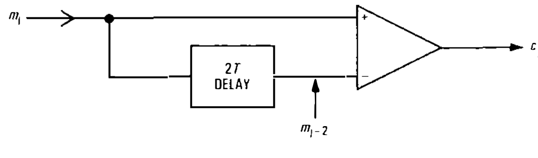


(*a*) Pre-coding circuit

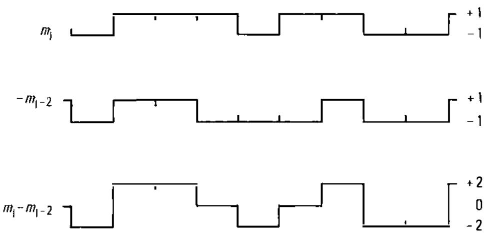


(*b*) Timing diagram
T=data unit interval
⊕=modulo 2 addition

FIG. 8—Pre-coding circuit and timing diagram

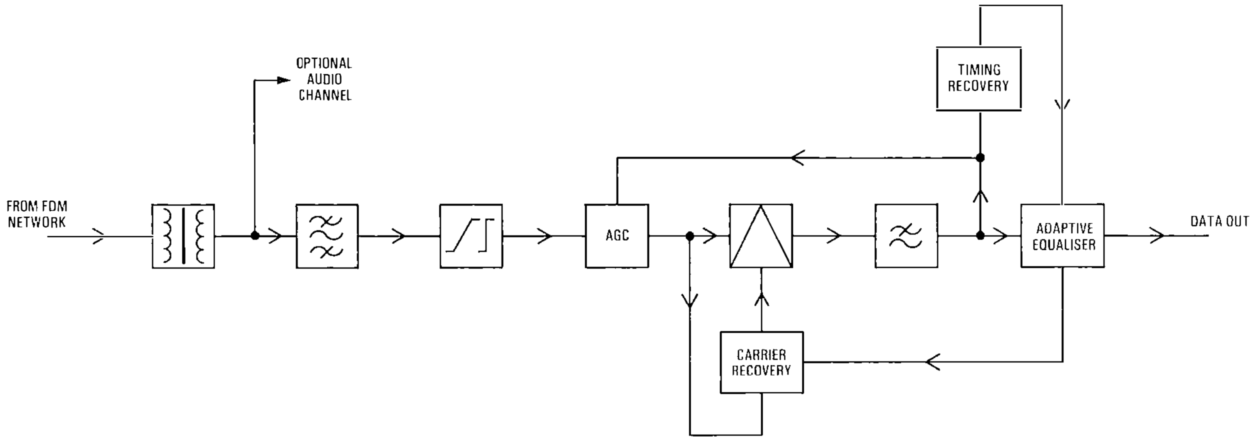


(*a*) Multiple-response circuit



(*b*) Timing diagram

FIG. 9—Circuit producing 1, 0, −1 multiple-response signal and timing diagram



AGC—Automatic gain control

FIG. 10—Modem 36 receiver

Figs. 8(b) and 9(b) reveals that $|c_j|$ is the same waveform as a_j, but delayed by $2T$; thus, the receiver can recover the original binary data sequence by full-wave rectification of the 3-level signal.

The baseband signal, c_j, is band-limited by a 36 kHz low-pass filter before being used to amplitude modulate a carrier of 100 kHz. The channel filter selects the lower sideband and a vestige of the upper sideband (60–104 kHz), and is followed by a delay equaliser to restrict the group-delay distortion to 8μs peak-to-peak, over 80% of the frequency band used. After filtering, a group-reference pilot and an optional audio channel can be added; the resultant signal is then transmitted to the group-band port via a 75 Ω unbalanced transformer at a nominal level of −43 dBm (−5 dBm0).

The Receiver

The receiver consists of a channel-filter card, demodulator and carrier-recovery card, timing-recovery card, quantiser card and an adaptive-equaliser card; the receiver is shown in block diagram form in Fig. 10.

The modulated line signal from the group-band channel is passed through an unbalanced 75 Ω transformer and amplifier, where the audio channel can be extracted if required. The signal is then band-limited to 64–100 kHz in a delay-equalised filter, and passed through an automatic gain control (AGC) amplifier, which is controlled by a voltage derived from the demodulated unequalised signal. The output of the AGC amplifier is demodulated in a balanced integrated-circuit demodulator.

The demodulated signal is passed through an initial post-detection filter, followed by an additional low-pass filter selected by straps to obtain the correct roll-off characteristic for each data rate. For 48 kbit/s operation, a 24 kHz low-pass filter is selected, and for 56, 60, 64 kbit/s rates, a compromise 31 kHz low-pass filter is used. For operation at 72 kbit/s, no additional filtering is necessary since the low-frequency cut-off of the channel filter, together with the initial post-detection filter, gives the correct roll-off characteristic. Timing recovery is achieved by processing the 3-level baseband signal to produce a strong timing component at the selected data rate[7]; this provides timing signals for the adaptive equaliser.

The demodulated unequalised signal is passed to the adaptive equaliser, where the binary data sequence is recovered. The data, timing and control signals are presented to the Modem 35 module.

A received line signal detector is operated by the outputs from a line-signal transitions detector, a signal quality monitor or an *extended RTS* signal control circuit. The line-signal transitions detector detects the presence of transitions in the signal at the output of the adaptive equaliser, while the quality monitor detects the presence of an error rate in excess of about 1 in 10^3. To generate the *extended RTS* control signal, the recovered binary data is connected to a V29 descrambler. While V35 scrambled data is being received, random transitions occur at the output of the V29 descrambler, and *RTS* signals remain ON. However, when a V29 pattern is received, caused by the *RTS* signal input to the transmitter going OFF, a steady binary one appears at the V29 descrambler output and turns the *extended RTS* signal control OFF. Any of these signals operates the received-line signal detector at the interface with the Modem 35 module transmitter.

CARRIER RECOVERY

A second-order phase-locked loop is used to recover the carrier from the pilot signal that is transmitted with the data. The voltage-controlled crystal oscillator used in the loop is designed to lock to a pilot signal having a frequency offset of up to ±8 Hz; this takes account of tolerances in the transmitter carrier oscillator (±1 Hz), and a possible frequency offset resulting from the various frequency translations in the FDM network.

Although the loop recovers the carrier in frequency and phase, the recovered phase is not necessarily the correct one for optimum demodulation of the received signal. This is because the 100 kHz carrier lies towards the band edge and undergoes an additional amount of phase shift relative to the main signal energy, depending on the characteristics of the group-band channel.

To correct for the phase shift, the recovered carrier is passed through a voltage-controlled phase-shifting (VCPS) circuit, before being used to demodulate the received signal. The VCPS circuit provides a continuously variable range of adjustment of about ±60°. If the control voltage attempts to move it outside this range (for example, during the initial acquisition period), the carrier phase is stepped by 90°. To reduce the likelihood of a sudden jump in phase occurring during the transmission of data, the range of the VCPS circuit is reduced to ±50° during the period of initial convergence of the modem. Once the modem has converged, and has been running satisfactorily for several seconds, the range of the VCPS circuit is extended by altering the control-voltage limits to allow at least a 10° margin before a jump in phase can occur.

The carrier phase that gives the best demodulated eye does not necessarily give the best equalised eye; thus, altering the carrier phase can degrade the demodulated eye, but improve the error performance of the modem. This is because the equaliser is able to cancel inter-symbol interference lying only within its time span. Changing the carrier phase, although increasing the overall inter-symbol interference, can reduce the amplitude of those inter-symbol interference components lying outside the range of the equaliser. Because of this interaction, the equaliser is the obvious choice for the derivation of the control signal that sets the carrier phase. With the distortion encountered on group-band circuits, it was found that, if the algebraic sum of the 2 leading and 2 trailing tap coefficients of the equaliser is zero, the carrier phase is very close to optimum. The sum of these taps provides a control signal with an ideal characteristic, having only one global minimum, giving a simple and satisfactory way of controlling the carrier phase.

As there is no requirement for a fast start-up for the Modem 36, the time constant of the summing integrator has been set at several seconds to prevent unwanted interaction with the other feedback paths in the timing-recovery circuit and in the adaptive equaliser.

TIMING RECOVERY

A second-order phase-locked loop, similar to that used in the carrier-recovery section, is used to recover the data clock signal from the demodulated line signal. The output from this circuit provides all the clock signals necessary for the correct operation of the adaptive equaliser and the data-recovery circuits. Because the equaliser depends on having correct timing information, it is important that the timing-recovery method used is relatively robust and insensitive to the phase of the demodulating carrier. Without this, problems could occur in initially converging the equaliser.

In order to ensure that there is always a strong frequency component present at the data rate for the phase-locked loop to lock to, the demodulated signal is fed through a series of processing circuits that rectify, slice and then fold the signal onto itself[7]. The resulting signal contains a strong frequency component at the data rate, which varies in amplitude by only about 4 dB between an in-phase demodulating carrier and a quadrature demodulating carrier, and provides the reference signal for the timing-recovery phase-locked loop. The timing-recovery circuits contain no frequency-sensitive components, and the phase of the recovered timing signal is close to optimum for all the data rates supported by the modem.

ADAPTIVE EQUALISATION IN THE MODEM 36

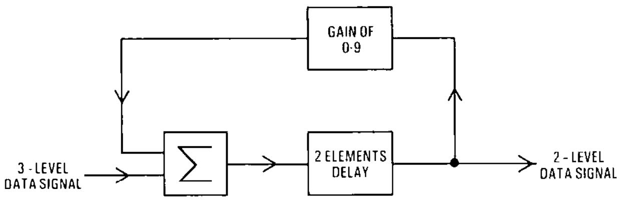


FIG. 11—Recursive circuit for reconverting to 2-level signal

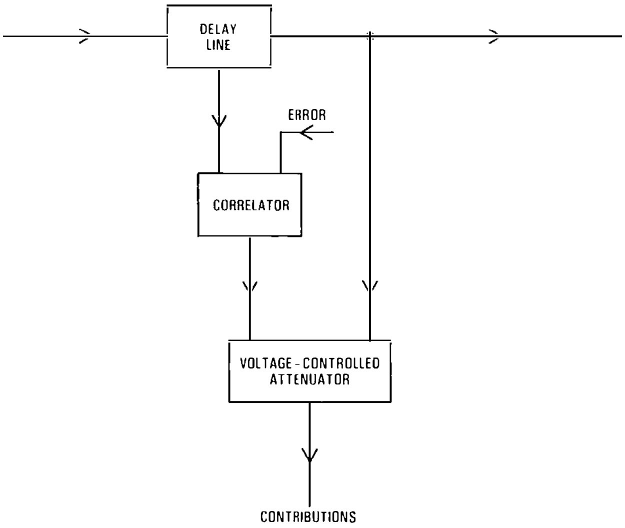


FIG. 12—Block diagram of an adaptive-equaliser section

The transmission characteristics of a group-band channel introduce dispersion into the received data pulse and a long delay line is required to hold all the data elements that contribute significant inter-symbol interference components. However, if multiple-response encoding is carried out within the adaptive equaliser, rather than in the transmitter, the delay line can be shortened[8]. This is because the error correction component required from the *n*th stage of the equaliser is proportional to the difference between the inter-symbol interference components from data pulses at time $t+T$ and $t-T$. Although there are a large number of inter-symbol interference components, this difference signal rapidly becomes very small for the type of distortion encountered on group-band links. This allows the length of the equaliser delay line to be significantly reduced, because the outer taps no longer contribute significantly to the error-correction signal. It also considerably eases the practical implementation of the equaliser since adding additional stages to the equaliser can degrade its performance through practical imperfections in the circuity; for example, offsets and noise.

However, CCITT Recommendation V36 requires the multi-response encoding of the signal to be performed at the transmitter although, in a linear system, there is no reason why this cannot be performed within the receiver. To meet the V36 Recommendation, but still gain the benefits of performing the multiple-response encoding in the equaliser, a 1, 0, −1 encoded signal is transmitted over the group-band channel and, within the receiver, it is reconverted to a conventional 2-level signal before it is passed through the adaptive equaliser.

This reconversion is achieved by using a recursive circuit (Fig. 11), in which the received signal, delayed by 2 elements, is added to the original 3-level signal. As the circuit is recursive, the feedback path is set to have a gain of 0·9 to keep the circuit stable. This is equivalent to division by (1, 0, −0·9) and results in a quasi 2-level signal at the output of the adder, which is then passed down the equaliser delay line.

In the adaptive equaliser of the Modem 36, the analogue delay line is implemented as a sample-and-hold delay line, clocked at the data element rate, *T*. The equaliser contains 9 identical sections, a summer, and a quantiser. Each section (Fig. 12) consists of one stage of delay, a correlator and a voltage-controlled attenuator. The operation of the adaptive equaliser is easier to describe if it is divided into 2 paths: the signal path and the compensation path.

The Signal Path

The adaptive equaliser is shown in block diagram form in Fig. 13. The quasi 2-level signal passes down the analogue

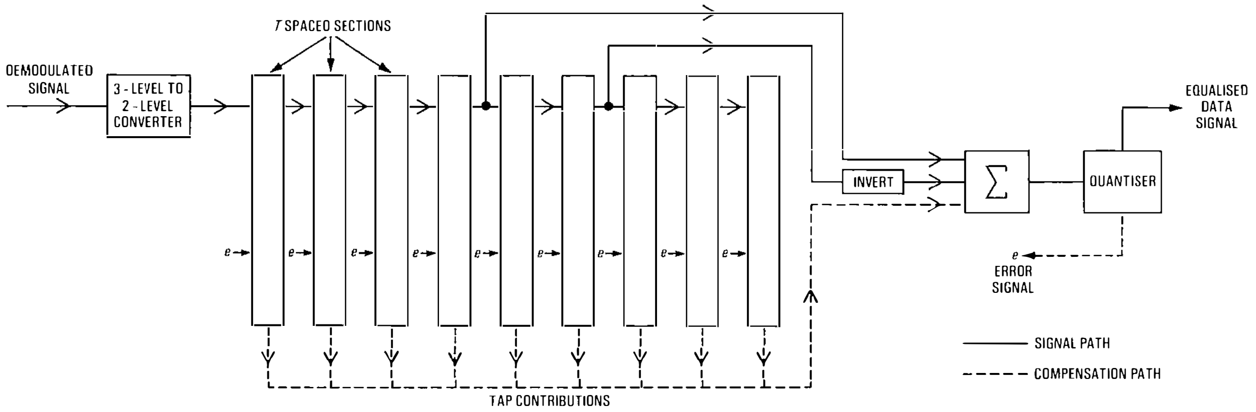


FIG. 13—Block diagram of adaptive equaliser

sample-and-hold delay line, in which each stage holds one received data element. Two signals are taken from the delay line, one from each side of the centre stage and separated from each other by 2 data unit elements (2*T*). These signals are connected to the summing amplifier where they are combined. The later signal path is inverted before it is connected to the summing amplifier. The effect of this circuit arrangement is identical to the 1, 0, −1 encoder in the transmitter (see Fig. 9). However, in this case, the applied signals are analogue, and the output of the summing amplifier is an analogue 3-level signal with nominal levels of +1 V, 0 V, and −1 V.

This signal is applied to the quantiser, where it is regenerated to exact levels of 1 V, 0 V or −1 V, from which the data is extracted. The control signal for the adaptive part of the equaliser is obtained by subtracting the regenerated 3-level signal from the analogue signal from which it was derived, in order to produce an error signal. This error signal is then fed back to the equaliser control circuits.

The Compensation Path

The equaliser provides correction signals, which are fed to the summing amplifier and added to the main 1, 0, −1 signal to remove the inter-symbol interference components present. These correction signals are taken from the output of the voltage-controlled attenuators in each section, which can pass a proportion of the signal held in the delay stage. The voltage-controlled attenuators are, in turn, controlled by the output of the correlators (see Fig. 12). The correlators, which are effectively multipliers followed by integrators, correlate the error signal with the data elements present in the delay line. If a component in the error signal always matches the element in a particular section, the correlator output of that section adjusts its voltage-controlled attenuator so as to reduce this correlation and, hence, provide a correcting signal to the summing amplifier to remove the inter-symbol interference produced by the element in that section.

The equaliser works directly on the incoming data stream and does not require any preliminary training pattern to be sent. While data is being transmitted, it is continually adapting and follows any slow changes that occur in the characteristics of the transmission channel.

MODEM PERFORMANCE

The Modem 36 has been extensively tested in the laboratory and there have been 4 successful field trials, including one over an international satellite link.

Laboratory tests show that the modem gives satisfactory operation at data rates of 48, 56, 60 and 64 kbit/s with up to 4 unequalised through-group filters and/or up to 6 equalised through-group filters in circuit. Fig. 14 shows a typical signal-to-noise/error-rate characteristic, measured in the laboratory at 64 kbit/s data rate, with 4 unequalised through-group filters in circuit. At 72 kbit/s data rate, satisfactory operation is achieved with up to 6 equalised

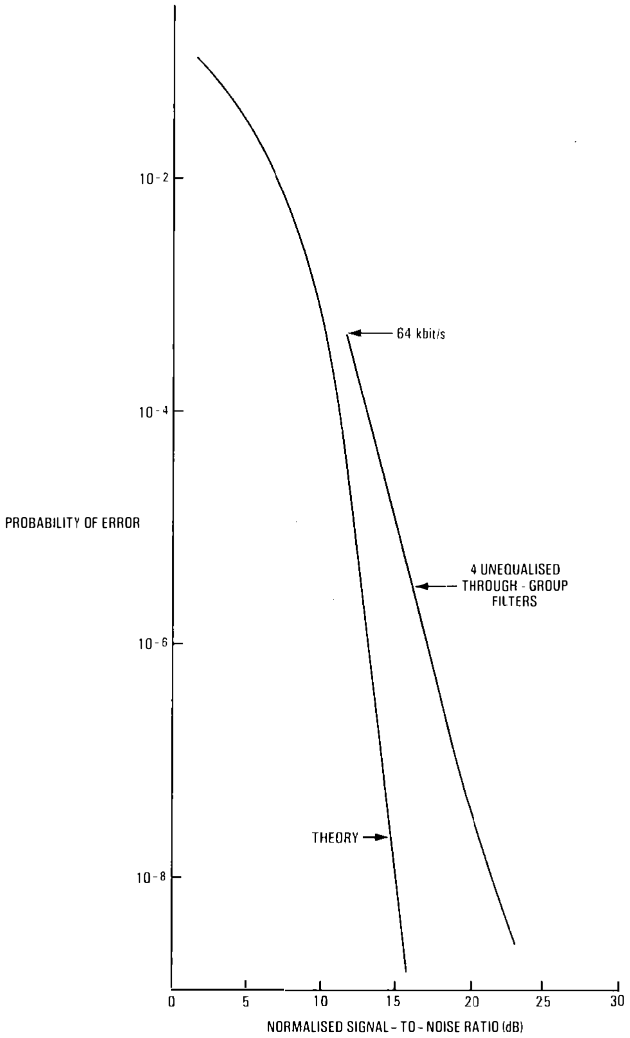
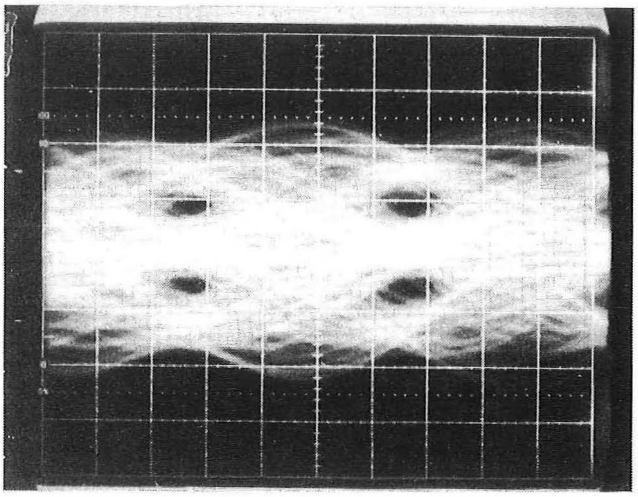
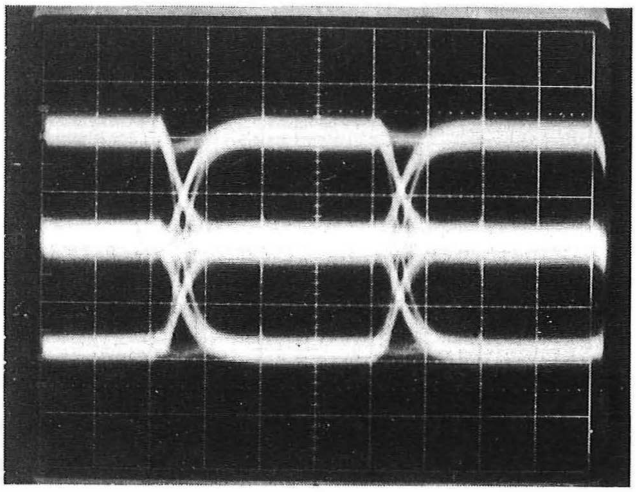


FIG. 14—Typical error-probability/signal-to-noise ratio characteristic



(*a*) Demodulated eye



(*b*) Equalised eye

FIG. 15—Performance of modem on typical circuit

through-group filters in circuit, but the modem gives satisfactory performance with only 1 unequalised through-group filter in circuit. In this context, satisfactory operation means that the modem adapted within a few seconds to the transmission characteristic of the link, and ran error free for at least 10^7 bits.

During the field trials, centred on Cambridge, Houndsditch and Wood Street Repeater Stations, over 40 different circuits were set up and the modem performance observed. Circuits with up to 9 unequalised through-group fitters, including edge groups 1 and 5, also group 3 and several radio links, were included in the field trials. From these tests, it appeared that satisfactory operation of the modem is possible, as follows:

(*a*) at 48 kbit/s with up to 7 unequalised through-group filters,
(*b*) at 56 kbit/s with up to 5 unequalised through-group filters,
(*c*) at 60 kbit/s with up to 4 unequalised through-group filters, or
(*d*) at 64 kbit/s with up to 3 unequalised through-group filters.

Satisfactory operation was achieved using any combination of groups including edge groups 1 and 5.

Fig. 15 shows a photograph taken with the Modem 36 operating over a typical circuit that could be met in the network; this included 3 unequalised through-group filters and used groups 1, 2, 4 and 5. The equalised eye is completely open, indicating that a good error rate performance is achieved at a data rate of 64 kbit/s.

CONCLUSIONS

With the future contraction of the FDM network, planning flexibility in allocating channels will become essential. With the Modem 36, the planning restrictions on routeing group-band data circuits no longer apply. The inclusion of an adaptive equaliser enables any group in the FDM network to be used and installation is simple, as through-group filters do not have to be delay equalised.

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A Test Facility and Design Consultancy for the Evaluation of Connection Systems

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UDC 621.315.683.001.4

This article describes a comprehensive range of test facilities that have been set-up at British Telecom Research Laboratories for testing connection systems, and that have recently been made available for use by Industry. It also describes a design consultancy that has been established to assist with the design and evaluation of connection systems.*

INTRODUCTION

Rapid growth in the electronics and telecommunications industries has led to a demand for new types of wire and circuit connections. These devices cover the whole range of static contacts from printed-wiring-board edge connectors to discrete cable connectors. Electrical contacts designed today invariably have to meet more exacting performance requirements than before. This is mainly because of the gradual decrease in operating currents of modern circuitry, but also because of the need for better contact stability to meet today's transmission requirements.

In the past, with the older types of electrical connection (for example, screw terminal or twist joint) the high operating current in a typical circuit was sufficient to penetrate any resistive film present at the contact interface, and so *wet* the circuit. Today, however, the much lower operating currents used cannot so readily penetrate the resistive films. The integrity of the circuit can be dependent on the presence or absence of these films. Consequently, any film, if allowed to form, can lead to the complete cessation of the circuit.

The increased reliance on connector performance has resulted in a great deal of research into new connection systems. As with any new connector design, it is always an advantage to predict service performance at an early stage. Research has shown that this can be achieved quickly by the use of environmental tests, which seek to duplicate and accelerate the service environment in the laboratory. Testing of this nature can help the designer by providing quick results, which should enable inexpensive design modifications to be made at an early stage. Unfortunately, some connector manufacturers do not possess the facilities to test their own products reliably, and others possess test equipment but not the technical expertise to interpret the results of their tests.

This article describes the connector test facilities that are available at British Telecom Research Laboratories (BTRL) (see Fig. 1). These facilities are available mainly to other British Telecom (BT) departments, but as a consequence of the British Telecommunications Act of 1981, they have also become accessible to Industry. A comprehensive range of test facilities and equipment which can cater for most connnection systems has been built up over a number of years. In addition, a design consultancy is available to assist manufacturers in optimising the designs of their connection systems.

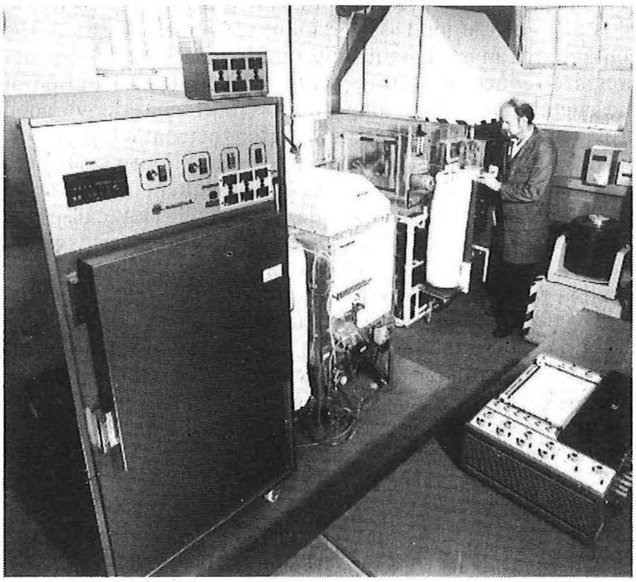

FIG. 1—Environmental testing laboratory

STATIC CONTACT

The term *static contact* refers to a releasable junction between 2 conductors that carry an electric current. These connection systems fall into many classes depending on such factors as contact pressure, contact permanence, separability and so on. The common factor with all of them is the presence of a contact resistance at the joint interface. This resistance exists regardless of the design of the connector or the nature of the materials in the joint[1]. For most practical purposes the contact resistance can be considered to be a combination of 2 factors:

(*a*) *Constriction Resistance* This is due to current flow being restricted through conducting spots on the mating contact interface. It depends on the contact pressure and the nature of the contact materials; for example, soft materials deform more easily than hard materials and normally produce more contact spots.

(*b*) *Oxide-Film Resistance* Any oxide film or insulating deposit in the contact area gives rise to an additional resistance. The film depends not only on the reactivity of the mating materials, but also on connector design factors such as contact pressure, contact surface finish and case geometry.

As the joint ages in service, the increase in resistance is primarily a result of the growth of the insulating deposits and oxide layer.

Typical examples of static contacts are bolted or screwed joints, crimp connections, plugs and sockets, relay contacts, printed-wiring-board edge connectors, wire wraps and insulation displacement connectors (IDCs).

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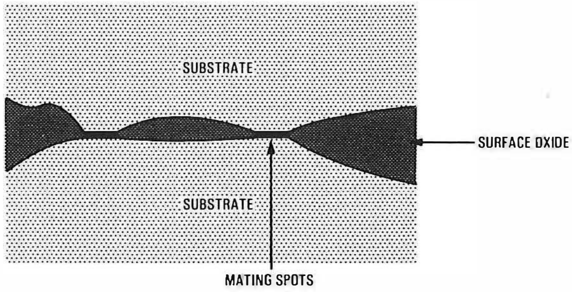


FIG. 2—Static contact interface

Fundamentals of Contact Design

The quality of a connection depends fundamentally on a combination of contact area and pressure. If the electrical resistance of the joint is to remain constant with time, the contact area must remain substantially constant. As contact pressure reduces with time, as a result of the relaxation of the metal parts, the connection is still considered good provided the atmosphere cannot enter the contact interface.

At high pressures the asperities of the 2 mating surfaces are tightly locked (see Fig. 2). A subsequent reduction in pressure within relatively wide limits will not cause the asperities to separate. If, however, the elastic energy which holds the 2 surfaces together is small, or is allowed to become small, a partial separation of the mating surfaces can occur and contact deterioration can take place. In other words, the atmosphere enters through the fringe of the original contact area, an oxide film grows and the electrical resistance increases.

Therefore, a good connection can be defined as one which has not only sufficient contact area and pressure, but also sufficient elastic reserve to maintain these parameters throughout the desired life. In this way, the atmosphere cannot enter the contact area, and the joint is said to be *gas tight*.

ENVIRONMENTAL TESTING

Environmental testing consists of any test or family of tests that seeks to duplicate in the laboratory the actual conditions that occur in service. The results, to be of any use to designers, must be obtained fairly quickly, and so the tests are accelerated to some degree[2]. It is here that problems arise because to design an acceptable test regime it is necessary

(*a*) to identify the mechanisms of field degradation,

(*b*) to preserve the failure mechanisms and the relationship between them in the laboratory, and

(*c*) to estimate the acceleration factor used in the laboratory so that components are not over or under tested.

In reality, it is almost impossible to satisfy all of the above criteria because of the complex issues involved. The problem is not insurmountable though because the test results can be viewed in 2 ways. Firstly, if the test is considered to be truly reproductive, the value of the results can be used as an absolute measure of connector performance. Secondly, in other tests, where the exact field mechanisms may not be reproduced in full, it is still possible to rank the performance of connectors over the test period. It is important to understand that, in both cases, the designer is helped by having an objective measure of connector performance.

TEST PROCEDURES

The environmental test laboratory at BTRL has been built up over a number of years. Various types of connector for the telephone network have been tested, and a database of results that can be used to set standards of performance for new systems is now available. The laboratory can reproduce any of the tests in BT's recently produced testing specification for static connections[3], including all the relevant test schedules in the British Standard covering basic environmental testing procedures[4]. There are also facilities for conducting a full range of subsidiary electrical and mechanical tests. The electrical tests include the determination of insulation resistance and termination resistance. The mechanical tests include the full range of conductor bending, pulling and flexing tests that are normally applied to test the robustness of a connector.

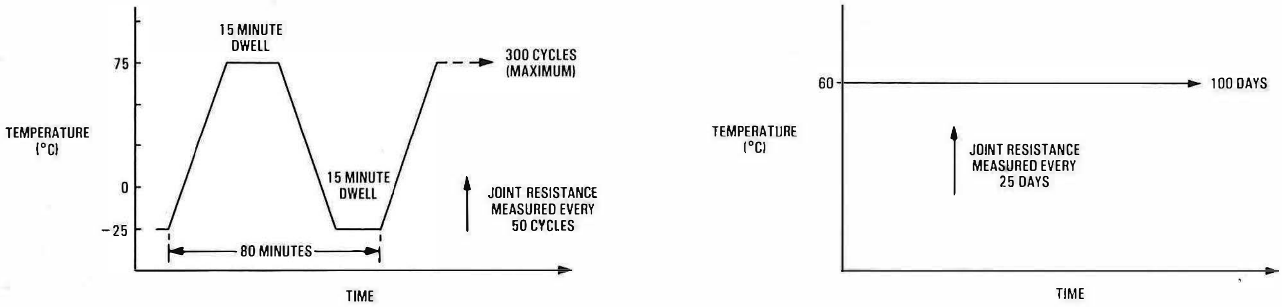
Temperature Cycle and Heat Soak

The testing schedule is arranged so that static contacts are given a core ageing test followed by specific service tests. The core test is a composite accelerated ageing test consisting of temperature cycling and heat soak in tandem. It is designed to reproduce the conditions of a full service life. An outline procedure for the core test is shown in Fig. 3, but the test is described fully in a previous article in the *Journal*[2].

Fig. 4 shows the contact performance criteria that are applied to new connectors used in BT's network. It is important to note that, as the network moves increasingly towards digital transmission, the integrity of the circuit connection becomes more important. For example, very low wetting currents ($\approx$4 mA) are used in digital systems, and so high resistance joints can lead to a loss of transmission. BT's new specifications for connectors limit the allowable resistance rise in a connector to 2·5 mΩ over the core test.

Other Tests

After the core test, connectors are subjected to a secondary series of tests designed to simulate other factors in the



(*a*) Temperature cycling test

(*b*) Heat soak test

Note: The core ageing test consists of temperature cycling followed by heat soak

FIG. 3—Core ageing test

environment, including exposure to industrial atmosphere, salt spray and vibration. Fig. 5 shows some typical results achieved during development trials of some IDC devices. The results for the salt-spray test were obtained on a grease-protected external connector, and the results for the sulphur-dioxide (SO_2) and vibration tests were obtained on exposed IDC contacts.

Industrial Atmosphere

The problem of designing a simulated atmosphere test for the laboratory is both difficult and controversial. The composition of real environments is complex and poorly understood and is, therefore, difficult to simulate in the laboratory. What is certain is that, for exposed contacts, the environment alone can have a significant effect on joint integrity.

Many studies of industrial environments have been carried out which have suggested that SO_2 is a prime factor in the degradation of contacts. Indeed, it is thought to be the most common and pervasive of all the corrosive air pollutants. As a result, an industrial atmosphere test was devised which consists of exposing connectors to an SO_2 environment of 25 parts per million for 21 days while the contact resistance is monitored.

Recently, there has been some controversy over the relevance of this test. Some workers suggest that it is too aggressive, does not bear relation to real environments, and does not give results that correlate with the corrosion that occurs on contacts in practice. Others suggest that it is useful for testing specific connector materials; for example, gold, palladium, and copper alloys. Useful results have also been produced on silver, tin and tin/lead components. It is also worth noting that some workers suggest that a hydrogen-sulphide test is better suited to produce realistic tarnishing on silver-alloy components.

In summary, although the SO_2 test may not give authentic results, it has proved useful in providing an indication of the service performance of exposed contacts.

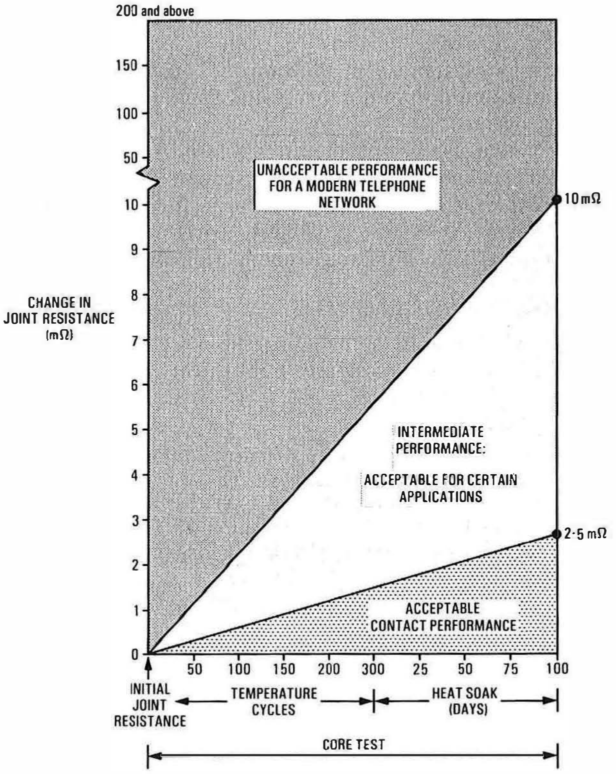


FIG. 4—Contact performance criteria

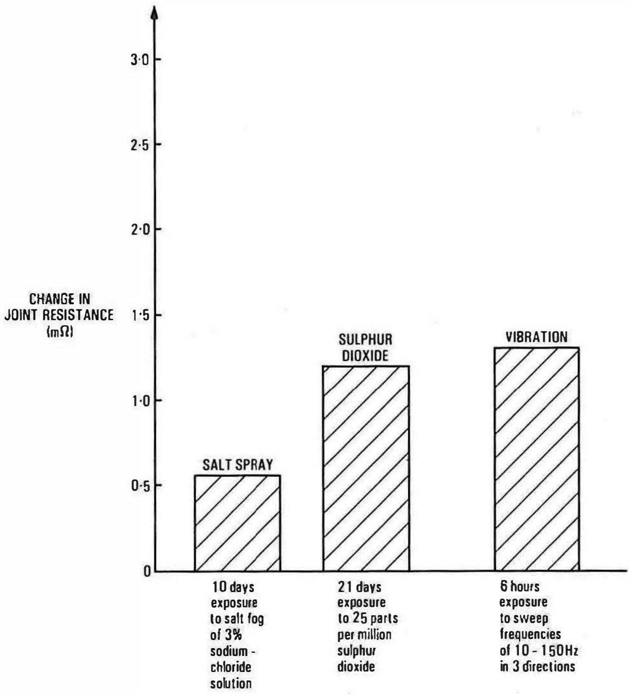


FIG. 5—Typical subsidiary test results

Salt Spray

The salt-spray test is designed to simulate a marine or sea-coast environment. It is a useful test in this country because the UK, being an island, has an extensive coastline. Furthermore, evidence has shown that the brine spray can penetrate up to 16 km inland. Typically, the test is used for external connections situated in boxes on house walls or on the tops of poles. In such locations it is common for the top of the box to be inadvertently left off, and this exposes the connections to the elements. This alone contributes to excessive maintenance costs in sea-coast locations. Therefore, it is an advantage to predict the likely service behaviour of a connector at its design stage.

The test consists of subjecting connections to a fine mist of 3–5% salt solution for a period of days. The results give some idea of the relative service life and behaviour of different samples of the same, or closely related, metals or coatings in these exposed locations. Caution should be exercised when the results of the tests are being interpreted because experience has shown that there is seldom a direct relationship between resistance to salt spray and resistance to other atmospheric phenomena.

Vibration

Vibration testing can be useful both in simulating the mechanical service environment and as a design tool to assess the structural integrity of a component. Two problems become apparent when a test schedule is being devised:

(*a*) It is difficult to analyse the service environment in terms of frequency and amplitude, as vibration in service is of a complex nature. In addition, the contribution of vibration caused by transportation and rough handling to the deterioration of contacts needs to be assessed.

(*b*) It is difficult to predict the precise effect that vibration has on a joint. It is certain that contact failures do occur because of vibration alone, but, with complicated designs of contacts and mouldings, it is difficult to analyse which parts vibrate and to what degree. Furthermore, regular visual inspections of test specimens need to be made because wires may move in a connector that is vibrated, yet a good joint resistance reading may still be obtained. In practice, to achieve a realistic result, engineering flair and judgement must be applied to the fixture designs and the general interpretation of the results.

In the tests carried out at BTRL, service conditions are simulated by vibrating samples through a range of sinusoidal frequencies. A wide band of frequencies, 10–150 Hz, swept at 1 octave per minute, is used. The test is used to determine resonant component frequencies, and so search out the mechanical resonance and other frequency dependent effects that will degrade the joint. In addition, components are subjected to a shock test involving 4000 bumps at a severity of 40*g* to complete the test sequence.

Fig. 5 shows results from a vibration test on a prototype IDC device. The increase in contact resistance was approximately 1·3 mΩ, but final production models would be expected to exhibit only a fraction of this value.

CONSULTANCY DESIGN SERVICE

A consultancy design service is available at BTRL to assist manufacturers in improving their connector designs. This consultancy is based on an ability to analyse the shortcomings of current devices and prototypes from both a structural and material point of view. Once the faults and deficiencies have been identified, suitable suggestions can be made for improving designs to meet particular circuit and environmental requirements. In short, a complete design service for connection systems is available.

Structural Analyses

The first step in improving a design is to analyse structurally the component parts of the connection. This process can assess, for example, the level of contact stress at particular parts of the joint. Ideally, in a non-separable connection the initial contact stress should be sufficient to compensate for the stress relaxation processes that occur in service.

With simple joint configurations, stress analysis can normally be done by using straightforward elastic-deformation theory. The results have been shown to hold true where both section shapes and stress distributions are uniform, but in most practical situations these 2 factors are complicated. The simple theory provides a first approximation of the stress values, but to obtain accurate results a more comprehensive analysis is required.

To overcome this problem extensive use has been made of the photo-elastic stress-analysis technique. By this method, it is possible to construct simple 2-dimensional models of the connection system under examination. The model is usually a scaled-up version of the contact interface. It is manufactured in a birefringent material, which, when exposed to polarised light, exhibits a series of interference patterns. These patterns are analogous to lines of stress, the position and value of which can be related back to the original contact.

Fig. 6 shows an example of the patterns obtained for a model of a double IDC split-beam connecting element. By careful analysis of the interference lines it is possible to deduce the stress distribution around the element. The maximum stress occurs not unexpectedly at the base of each slot, where the density of fringes is greatest. Furthermore, the contact stresses can be observed as a localised area of fringes at the wire position. Although analysis of different shapes of models requires a degree of familiarity with the technique, current results have shown that the photo-elastic method is a quick and powerful stress-analysis tool.

Metallurgical and Material Analysis

The second part of the consultancy service is concerned with the analysis of materials in the connector. This includes both the selection of suitable metals and plastics to form the connector body and the choice of contact coating to ensure a long-term low-resistance contact. The importance of this latter point cannot be overestimated because the wrong choice of contact coating can lead very quickly to a high-resistance joint.

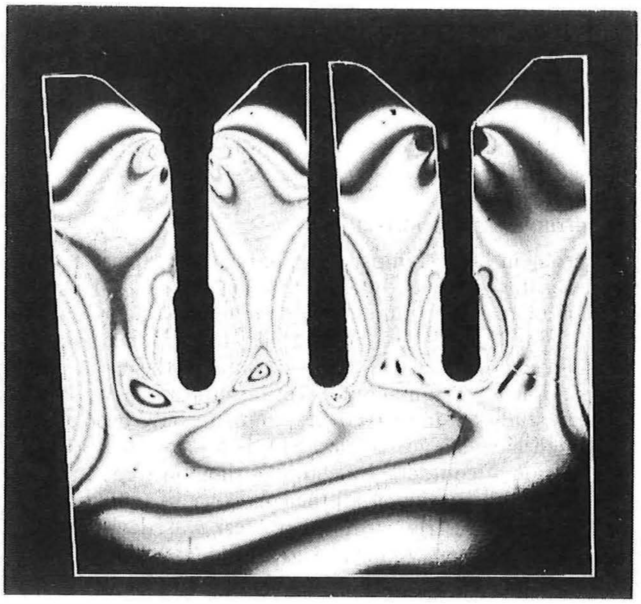


FIG. 6—Photo-elastic stress-analysis model

Examples of Project Work

Some examples of project work that have been carried out on connection systems at BTRL are described in the *Journal*; they include wire-wrapping devices for aluminium cables[6], IDCs[7], and connection systems for aluminium cables[8].

CONCLUSION

At BTRL, a comprehensive connector test facility is available to BT departments and manufacturers. This offers a comprehensive range of tests to evaluate all types of static connection systems. In addition, a consultancy service is available to aid manufacturers and users in optimising connector designs.

To make use of the facilities offered by the laboratory, the BT Technology Consultancy scheme (previously known as *Friends of Martlesham*) has been formulated. Through this scheme, it is now possible to carry out sponsored test and research work on static connection systems.

ACKNOWLEDGEMENTS

Acknowledgement is made to the Director of Research, BTRL, for his permission to publish this article.

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An Unusual Gas Problem

C. ATKINSON†

INTRODUCTION

On 3 December 1979, 2 incidents occurred in the Leeds Telephone Area which, because of their serious nature and the subsequent consequences, have taken about 3 years to resolve. Fig. 1 shows a map of the location concerned and the plant involved.

THE INCIDENTS

At approximately 10.00 hours, 3 members of a works jointing party entered manhole A (see Fig. 1), after carrying out all the relevant gas safety checks, to undertake some pair diversion work. During the course of this work, at a period when the chamber was vacated, some of the cables in the manhole caught fire. All the cables in the manhole were polyethylene sheathed and were giving off black acrid fumes which made it difficult to get to the source of the fire. The Fire Brigade was summoned, but the party was able to extinguish the flames with water before they arrived. The source of the fire was not established.

The maintenance group was contacted to arrange for the repair of an 8-tube coaxial cable and several multi-pair cables that had been damaged in the fire. By approximately 18.15 hours, the cabling work had been completed by a maintenance party and 2 jointing parties had arrived on site, when the second incident occurred. Two jointers were in manhole B installing fluorescent lights (no other lighted appliances were in the manhole), when a sheet of flame shot out of the duct on the east side of the manhole. One of the jointers was scorched around the face and was taken to hospital for treatment.

Again, gas tests carried out before the work was started proved negative. The jointers could not judge the duration of the flame, but remembered that it was intense. They also remembered it tailing back and dying down up the duct mouth on the east side. Gas tests taken at adjacent manholes showed concentrations of explosive mixture varying between 20% and 100%. As with the normal practice for these incidents, the local gas authority was informed and the site closed down.

On the following day, the damaged multi-pair cables were restored by using the emergency access procedure specified in Telecommunications Instruction E3 H1114, and the systems on the coaxial cable were transferred to other cables.

INVESTIGATIONS

Preliminary investigations concentrated on the possibility that the gas had escaped from the gas mains. However, the analysis of gas samples taken from the plant indicated an absence of certain constituents normally present in domestic gas.

A survey of the area revealed several potential sources of methane gas, almost all of which could have contributed to the problem. These included old mine workings and coal outcrops, sewage works and collection systems, a factory processing animal fats and skins, and a solid-waste disposal tip. If progress was to be made, it was obvious that a logical sequence of testing, sampling, analysis and elimination was necessary to identify the source of the gas.

The mine workings were discussed with engineers of the National Coal Board and eliminated from further consideration because the constituents found in mine gas were not present in the samples taken from the plant. Discussions with West Yorkshire Metropolitan County Council's main drainage section revealed that collection systems are subject to very heavy liquid flow; consequently, solid effluent is unlikely to remain stationary for periods long enough to allow the build-up of gases within the system. Samples taken from these systems proved that they were an unlikely source of the gas. The examination of samples from the drains of the factory processing animal products also showed that there was no discharge of materials likely to cause the generation of gases.

After other possibilities had been eliminated, the investigation was concentrated on the solid-waste tip. It was already known that tips produce gases similar in type to that sampled in the manholes, but the connecting link between the tip and the duct route was unknown. Over a period of many weeks gas readings were taken regularly at a number of points. This resulted in a set of maximun readings at locations which formed a line roughly parallel to a known geological fault, and which were identical to those taken on the tip. However, the accuracy of the line was not sufficient to establish beyond all doubt that gases generated in the tip were migrating along this fault to the duct route.

The assistance of the West Yorkshire Metropolitan County Council was sought to examine the road construction plans for the area and find, if possible, any drain, culvert, or channel, temporary or permanent, which could have still been in situ and could have formed a path.

However, despite the evidence gathered by British Tele-

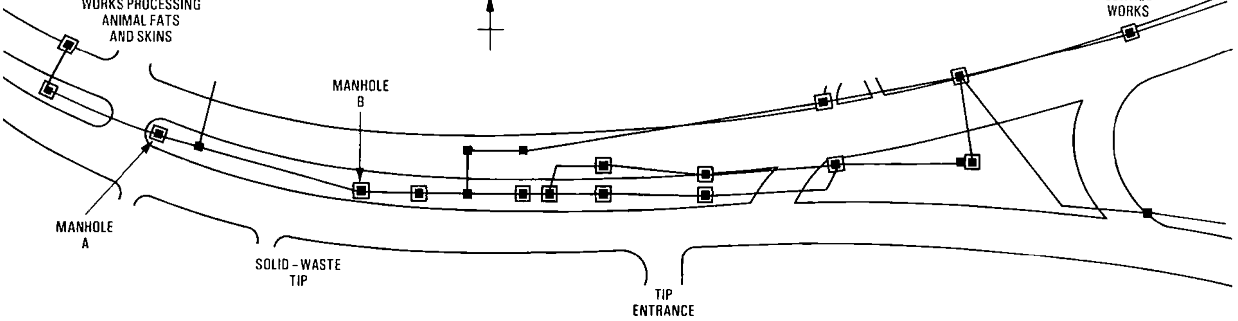

FIG. 1—Map of the location of the incidents

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† Leeds Telephone Area

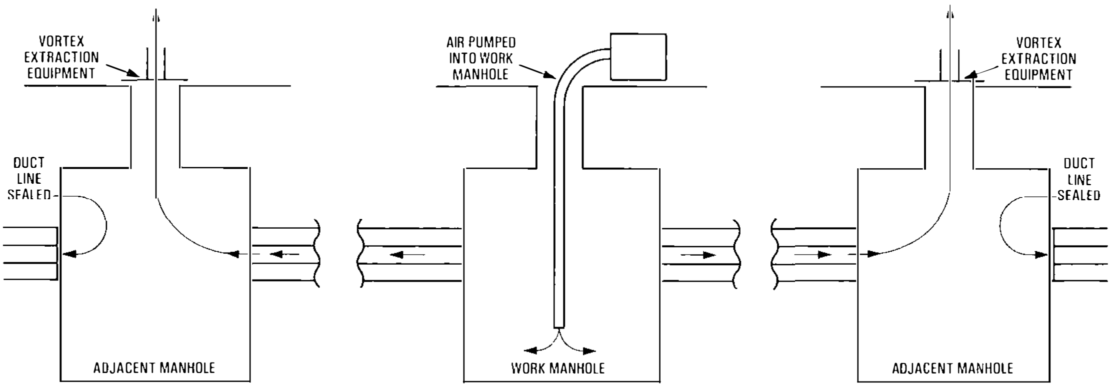

FIG. 2—Method of gas extraction

com's (BT's) consultants, it has not yet been possible to prove conclusively the path being taken by the gas from the county council's tip. There was some concern that the civil engineering work on the scale envisaged to investigate the problem would have been very expensive, with the possibility that no solution to the problem would be found. The county council wanted to be absolutely certain of the route being followed by the gas before commencing any work.

RESTORATION

The cables were completely restored during March 1982. Special vortex extraction equipment, developed by BT Headquarters Works Practices Division, was used to ventilate the plant and create a safe environment while the restoration work was in progress (see Fig. 2). While air was pumped in at the working manhole, vortex extractors drew the air along the duct route on either side and vented any gas present into the open air. The manholes parallel with the tip were fitted with ventilation stacks and lockable frames and covers to prevent free access. A strict code of practice was agreed between management and staff associations should the plant ever need to be re-entered.

CONCLUSION

A permanent and effective solution to the problem is being sought by BT's management through negotiations with the county council. The difficulties of the task should not be underestimated, and that it may be some time before the problem is finally resolved and the site is made completely free of gas.

The Evaluation of a Point-to-Multipoint Subscriber Radio System in Plymouth

B. P. MAUNDER†

INTRODUCTION

A point-to-multipoint subscriber radio system was recently installed in Plymouth for evaluation purposes. The main emphasis has been to investigate the procedures and practices for the planning, installation, commissioning and maintenance of such systems. The present equipment provides conventional speech channels, but this is regarded as a forerunner to digital subscriber radio equipment which will be required to provide 64 kbit/s data channels to customers' premises. This article briefly describes the equipment and some of the planning and installation aspects of the trial.

THE SYSTEM

The system, which was designed and manufactured by SR Telecom, Canada, is a microwave system used to connect exchange equipment situated at a central station in Plymouth Exchange to a number of outstations (see Fig. 1). The system operates in the 1·7–1·9 GHz frequency band. Only 2 radio-frequency bearers are used, one for transmission from the central station simultaneously to all the outstations, and a second for transmission in the opposite direction. Outstations transmit sequentially in burst mode.

Fifteen time-division multiplexed channels are used as trunks between the central station and the outstations, and a sixteenth trunk is used for the system control.

A line-of-sight path is normally required between the central station and each outstation. The range of the system is governed by topography, but is estimated as being up to 40 km.

Equipment to provide 6 outstations was purchased; of these, 3 have been installed, a further 2 have yet to be provided, and the sixth is set up to work at the central station and is used for testing and maintenance purposes.

Central Station

The central station can provide service for up to 94 customers (2-wire circuits), but equipment for only 30 customers is provided in the system at Plymouth and includes 27 exchange lines, two 2-wire private circuits and one 4-wire private circuit.

The equipment at the central station comprises a 4 W transmitter, a receiver, multiplexing system, timing synchronisation unit and alarm indication equipment. Stand-by radio and power equipment is also provided. The equipment is rack mounted and is connected to an omnidirectional aerial mounted on the roof of the building (see Fig. 2).

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† Plymouth Telephone Area

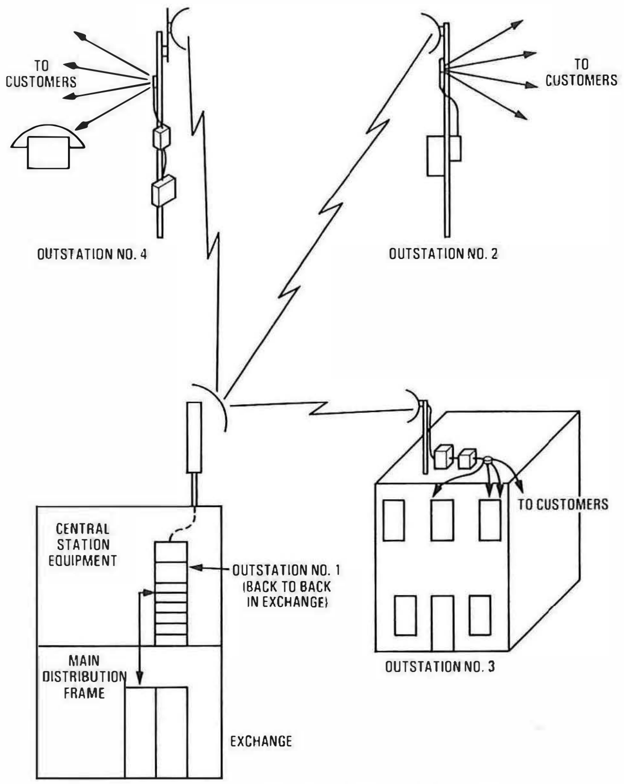

FIG. 1—Plymouth subscriber radio system

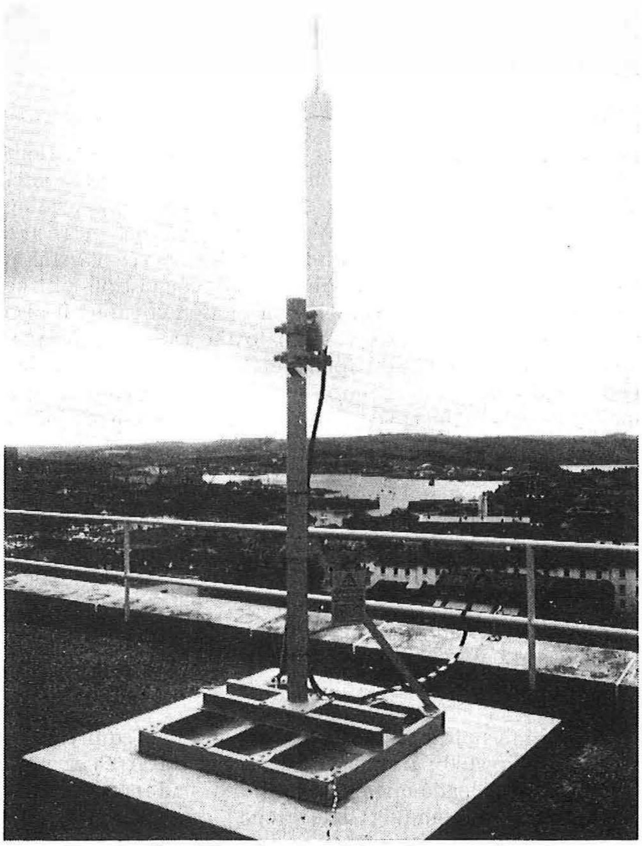

FIG. 2—Omnidirectional aerial at the central station

Outstations

Each outstation offers an initial capacity of 6 customers lines, but this can be extended if required. Customers are connected to the outstation by cable or dropwire.

Two of the outstations are mounted on poles (existing distribution points) (see Fig. 3) and a third is mounted on the roof of a block of flats.

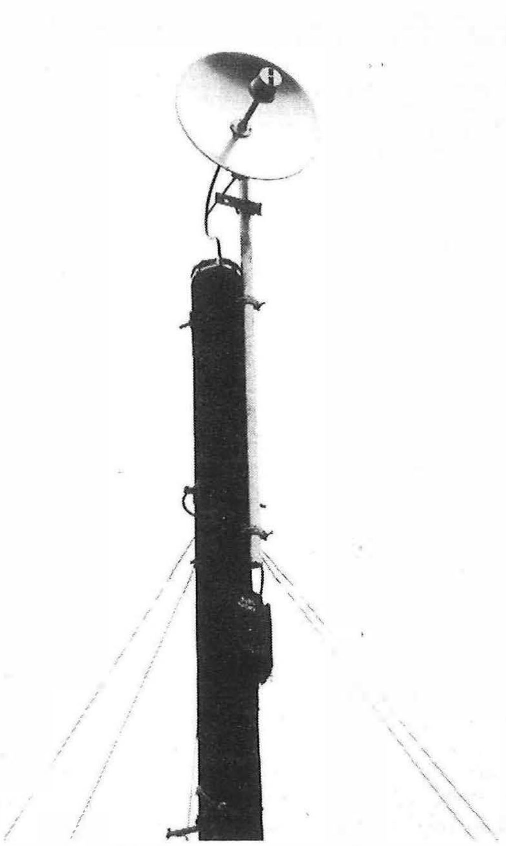

FIG. 3—Pole-mounted outstation

The outstation equipment comprises a 4 W transmitter, together with a receiver, time-division multiplex channel cards, customers' loop cards, interface equipment and a power unit. The equipment operates from the mains electricity supply and is furnished with an internal ringing generator and back-up batteries. The equipment is housed inside 2 cabinets, the larger one containing the radio and electronic units, the smaller containing lightning protectors, mains power equipment, fuse and switch.

At present, each outstation uses a pole-mounted parabolic dish aerial, 600 mm in diameter; however, further trials are envisaged for which shrouded Yagi-type aerials will be used.

PLANNING ASPECTS

Since the system is being used as an alternative to the provision of local line plant, it has been placed under the control of a Planning Group officer. The provision of additional lines and outstations will be justified by the planners, and all the necessary instructions, including jumpering details, will be supplied by the planning department.

The recording of the subscriber radio circuits follows a similar pattern as that for recording cable pairs, with the exception of the cable and cable-distribution diagrams, which do not show any lines connecting the radio distribution point to a flexibility point. The letters SR in front of the distribution point or pair reference indicates that the routeing is via the subscriber radio equipment and the microwave link. Radio distribution terminal blocks are similarly marked on Ordnance Survey maps.

CONCLUSION

Stores for the subscriber radio system arrived in Plymouth on 19 April 1982. Area staff installed and commissioned the equipment within one month, and the system was brought into service on 19 May 1982. There has been first-class cooperation from all the Area staff concerned, and from both the Regional and British Telecom headquarters staff involved.

The Provision of a New Duct Route Across Weymouth Harbour

P. SAYERS, and L. H. MOCKRIDGE†

INTRODUCTION

The provision of service for new customers south of Weymouth, and the Portland area in particular, was considerably delayed when the last available duct across Weymouth Harbour was rendered unusable because of a blockage. This article describes the methods used to provide a new duct route across the harbour and the problems encountered in planning and executing the work.

BACKGROUND

Weymouth Town stands on a peninsular with the English Channel to the east, a boat basin and lake to the west and the harbour to the south (see Fig. 1). Two road bridges connect the peninsular to the mainland; one of these, Westham Bridge, has a normal carriageway surface of limited depth and the other, Town Bridge, is of bascule construction and lifts in cantilever fashion from each shore. Ducts are laid in the carriageway of Westham Bridge and in the harbour bed close to Town Bridge. The latter route, laid in 1929 at the time the present bridge was built, consists of 3 steel ducts bedded in concrete.

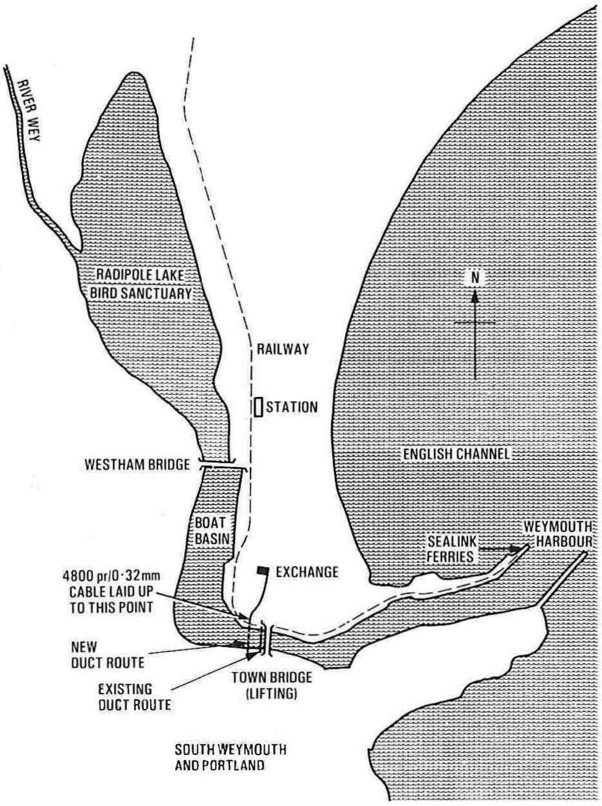

FIG. 1—Outline map of the area

The stage had been reached when 2 of these ducts were full. A 4800 pr/0·32 mm cable in one duct had just sufficient spare pairs on which to transfer customers from a cable in the third duct to enable the third duct to be cleared to make way for a further 4800 pr/0·32 mm cable. The new cable would provide sufficient pairs to meet all requirements including demand south and west of the harbour for at least 10 years.

The cable transfer was effected and the third duct was cleared and cleaned. The new 4800 pr/0·32 mm cable was laid in one continuous length along an old and difficult track to the harbour crossing and preparations were made to cable the underwater section. The cable became jammed in the duct under the harbour and had to be recovered for further duct cleaning operations, during which a test length and brush also became jammed. Considerable effort and ingenuity were used in the attempt to clear the duct, but the discovery of crabs and harbour debris in the duct led to the conclusion that the steel duct was probably breaking up. Further attempts were abandoned to avoid jeopardising the cables in the other 2 ducts. A new route across the harbour was therefore required.

PLANNING

Bournemouth Telephone Area Planning Group carried out extensive surveys to select the best line for a new duct route. Two factors finally tipped the scales in favour of providing another duct route across Weymouth Harbour near the Town Bridge. Firstly, the alternative route via Westham Bridge contained no spare ducts and congestion of the existing plant made a new duct route impracticable; it also would have added nearly 1·5 km to the cable route. Secondly, approximately 800 m of the 4800 pr/0·32 mm cable had already been pulled into duct from the exchange to a manhole close to the harbour crossing and its recovery intact was likely to be difficult.

Preliminary planning work by the Area staff included a survey of the harbour bed by divers to ascertain the depth of silt and the nature of the ground beneath it; also, discussions took place with the Harbour Master as to his requirements for a British Telecom (BT) duct crossing. The local authority was approached for information about the construction of the harbour retaining walls and British Rail (BR) consulted concerning their line between Weymouth Station and the Sealink terminal under which the new ducts would pass.

The findings of these investigations and the requirements of other interested parties were such that the Area and BT South West Headquarters staff (who had now become involved in the planning) had second thoughts about the harbour route. The information gathered by the Area staff showed that, on the north side, there were 2 old harbour walls in addition to the existing reinforced-concrete wall. The first of these was thought to be made of greenheart, a very hard wood, and the second of granite blocks. The position of the railway line and the scheduling of freight and passenger trains meant that open-cut working would be very difficult and was not favoured by BR. The south side of the harbour contained an old harbour wall of granite blocks. The construction of this and the reinforced-concrete wall

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† British Telecom South West and Bournemouth Telephone Area, respectively

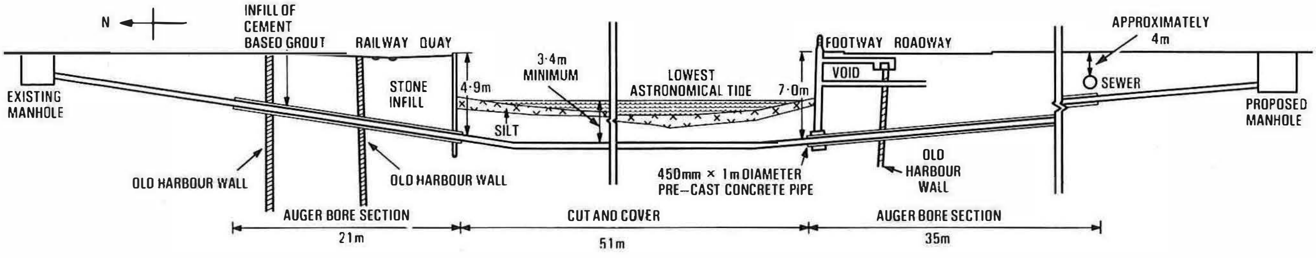


FIG. 2—Section through the harbour

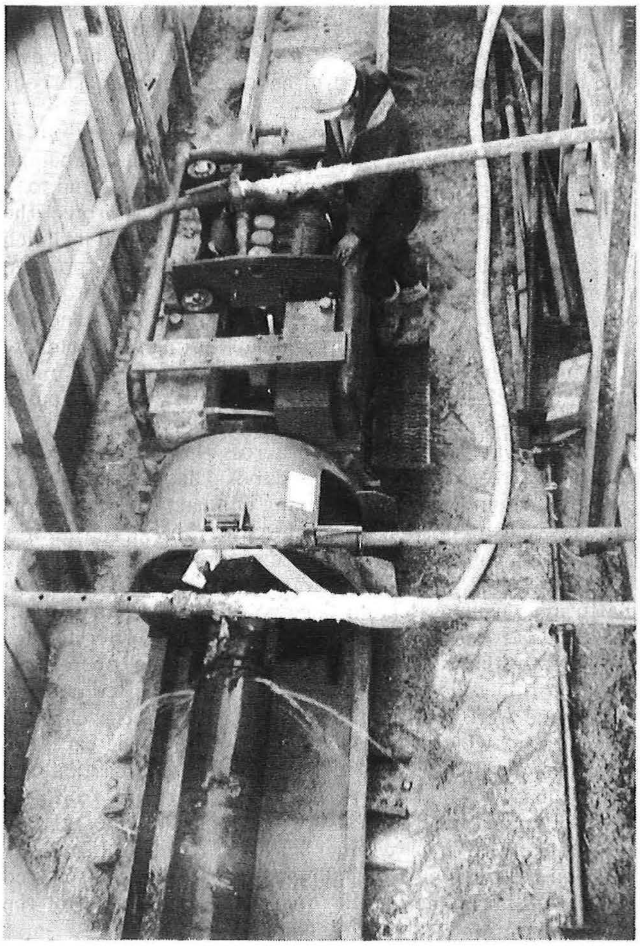


FIG. 3—Drilling machine in use on the south side of the harbour

were examined in detail from within a void between the 2 walls.

The Harbour Master stipulated that the minimum depth of cover over the duct should be 2 m from the top of the river bed. This meant that, as there was up to 1 m of silt, a 3·5 m deep trench had to be excavated. In addition, the Harbour Master stipulated that all surplus excavated material be removed from the site, since the main channel of the harbour to the east and west of Town Bridge was to be dredged at some time in the future. Fig. 2 shows a section through the harbour and the plant to be installed.

In view of these new considerations a further look was taken at the early planning proposals. Two alternatives were then considered:

(*a*) the re-assessment of the Westham Bridge route; and
(*b*) the use of the original proposed route but at a greater depth.

The method considered for the latter proposal was the mini-tunnel system in which a miner, working within a shield, excavates the soil in front of him and leaves a concrete segmented tunnel behind.

The first proposal was still found to be unsuitable for the reasons previously stated. The second was eliminated because of the need to construct deep manholes on both sides of the harbour well below the tide table and because of the problems of linking to existing ducts. On pricing this method, with all the new factors taken into account, it was found that the cost was likely to be 3 times that estimated for the original proposal. The 1 m diameter concrete tunnel would also have been largely wasted on the few ducts required. Fortunately, during discussions on proposals (*a*) and (*b*), a third possibility came to the attention of the regional staff and it was this method, a specialist technique of auger boring, that was finally used.

The overall problem was discussed with the External Works Practices Group in BT Headquarters, who produced a variety of suggestions for consideration, including an auger machine with a rock-drilling capability (see Fig. 3). This machine, made by the American Auger Company, rotates and pushes the steel casing, unlike conventional auger machines in which an auger rotates within the casing as it is pushed into position. The rotating casing gives the machine an increased capability in hard or rocky ground as a rock drill can be attached to the leading end (see Fig. 4). Enquiries were then made of the only British firm possessing such a machine to see if it could tackle the task of drilling through the variety of wall materials on both sides of the harbour. The firm stated that they would be able to carry out BT's proposal to drive a 300 mm diameter steel pipe by auger methods on each side of the harbour. This steel pipe would contain six 90 mm internal diameter polyvinyl-chloride (PVC) ducts (Ducts No. 54D), which would adequately

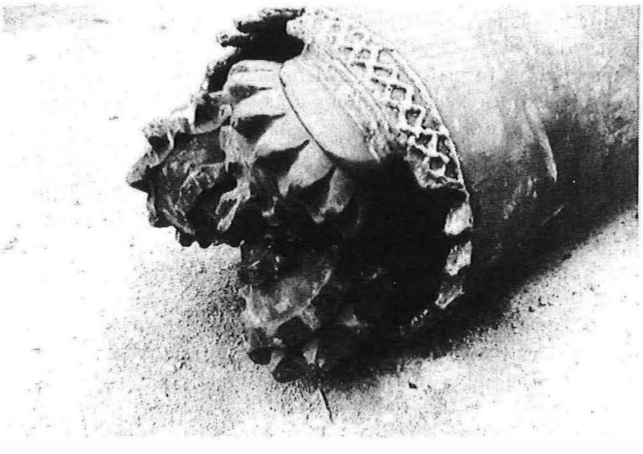


FIG. 4—Rock drill welded to the leading edge of the 300 mm diameter steel pipe

meet the Area's requirements for the next 20 years. The pipe would be driven from pits to the outside of the harbour where divers would lay the PVC ducts in a trench across the harbour.

The next stage was to obtain BR's agreement to auger beneath their railway line. This agreement was given, subject to the condition that the interstice of the duct within the pipe was filled with a cement-based grout. It was known from previous underwater ductwork schemes, elsewhere in the UK, that an open-cut crossing of the harbour by competent divers was feasible. In addition to the divers excavating and laying ducts in the harbour bed, it was proposed that they would also extend the duct, through the 300 mm diameter steel pipes, into both auger-boring thrust pits. Finally, it was decided that the provision of linking ducts and jointing chambers on the land sections of the cable route should be executed by one of BT's ductwork contractors.

CONTRACT PREPARATION

With the stages of work clearly defined, it was decided to prepare the contract documents in 3 parts. Two would be for specialist contractors (that is, auger boring and diving) and the third to a ductwork contractor for conventional ductwork and the necessary support work for the specialist firms. Because of the special nature of the work, specifications and drawings were prepared to cover the 3 stages, in addition to BT's Specification LN139 and standard drawings.

The auger boring was let on a non-competitive basis, as only one contractor in the UK had the machine and the capability. The diving work was tendered for competitively and because of the need to excavate the first thrust pit at short notice, the ductwork element was added to an existing contract in the same location, where a very competent firm was operating.

EXECUTION

The ductwork contractor commenced the excavation and timbering of the thrust pit on the north side of the harbour in mid-February 1982. In order that the pipe should enter the harbour at the required depth, with the thrust pit as shallow as possible, the concrete floor of the pit was sloped downwards at an angle of 12° to the horizontal and rails were provided to carry the auger machine (see Fig. 3).

The machine and associated equipment were brought to site and set up shortly afterwards, and drilling began within a week. The auger machine was moved forward, by the pressure from hydraulic rams, able to exert up to 250 t, acting on the track secured to the base. Because of the restricted space in the pit, 3 m lengths of steel pipe were used on the north side. After each length of pipe had been pushed into place, the machine was backed-off, a further length of pipe was welded into place and the drilling was restarted. The pipe and the rock drill (see Fig. 4) were lubricated by water fed through the machine and pipe. It took 11 days to provide the 21 m of steel pipe on the north side. The unforeseen problems encountered during the first drive were as follows.

(*a*) An exposed and damaged storm water pipe, which normally drained into the harbour, limited the drilling operations to periods of low tide. Reverse flow through the pipe regularly flooded the thrust pit and this meant that the machine had to be removed from the pit, by crane, each time the tide rose.

(*b*) The strain placed on the machine when the middle harbour wall was encountered was so great that the track on which the auger machine ran was lifted from its concrete bed. Remedial action included additional strengthening features recommended by BT's engineer on site.

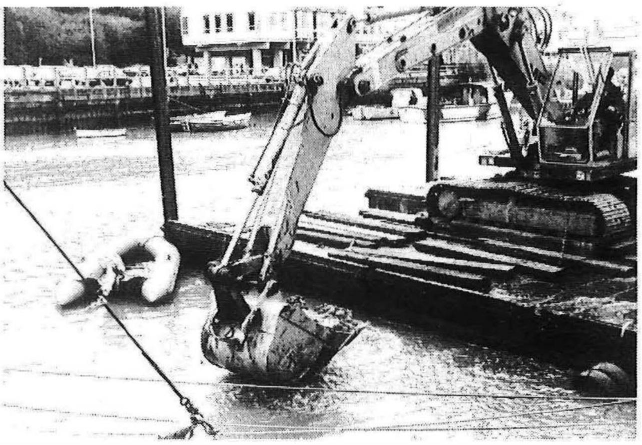
The equipment was then moved to the south side in preparation for the second drive. The start was delayed as the rock drill used on the first drive had to be recovered from the leading end. This was undertaken by using an underwater thermal lance once it had been successfully located by the diving contractor's staff. Because of the tidal conditions, this operation took 2 days.

The second drive began in mid-March and took 8 days to lay the 35 m of pipe. As on the North side, unforeseen problems arose. The first 6 m length dropped downwards slightly at the start of the drive and this resulted in a fracture in the weld at the machine end. A contributing factor may have been the deflection of the unsupported length of pipe outside the pit in unstable sub-soil. Drilling was stopped, the pipe withdrawn, the error corrected and the drive restarted. However, the water inlet boss used to lubricate the rock drill had been broken off when the pipe was withdrawn. Satisfactory progress was made beyond the old harbour wall, but as the pipe neared the end of the drive, the absence of lubrication caused the pipe to first stop rotating and subsequently to come to a halt 1 m short of the main harbour wall.

Prior to the main diving operations being carried out in the harbour bed, the end of the pipe had to be located behind the harbour wall. This operation was very difficult and took nearly 3 weeks. Safety precautions necessary to protect the divers and maintain the stability of the harbour wall included the provision of a 450 mm by 1000 mm diameter pre-cast concrete ring around the end of the steel pipe, the provision of a length of 300 mm diameter PVC pipe to extend the route beyond the harbour wall and back-filling with concrete contained in hessian bags. The auger bore achieved, under unusual conditions, most of the objectives, but without a good diving firm might well have been delayed longer.

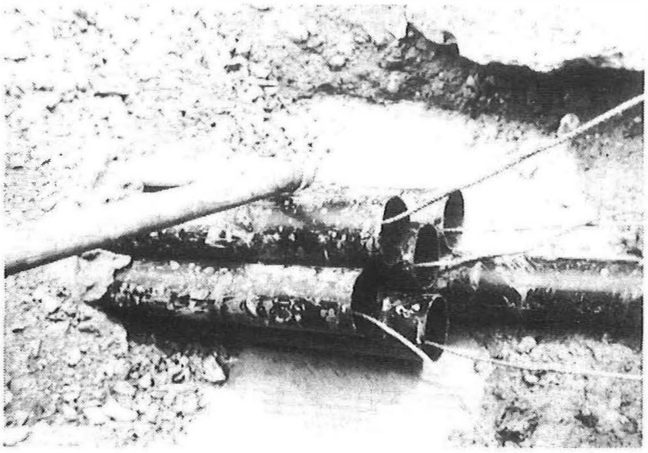
The excavation of the trench across the harbour to link both pipes started in mid-April and took 4 days. As instructed by the Harbour Master, the diving contractor removed the surplus excavated spoil from the site. The material was placed in a motorised barge and disposed of approximately 1·5 km off-shore. The trench was excavated from a floating platform by using a Poclain Excavator with a 3-part extending arm and a 1·5 m wide/0·5 t bucket. In order to give stability to the platform during the digging operations, self-adjusting rolled-steel joists (RSJs) were fitted at each corner and were retained in position by brackets welded to the platform which gripped the RSJs to prevent excessive tilt. This method worked exceptionally well, particularly when there was a need to move the platform from the deep-water channel when fishing and pleasure boats were entering and leaving the inner harbour. (See Fig. 5.)

When the excavation was finished, pea gravel was placed on the bottom of the trench to level the base ready for the



Note: Two of the self-adjusting RSJ stabilisers are visible

FIG. 5—Bucket excavator digging the trench across the harbour



Note: The small pipe on the left-hand side is for injecting cement-based grout

FIG. 6—Six PVC ducts within the 300 mm steel pipe

duct-laying operations. During the next 8 days, the 6 PVC ducts were laid across the harbour and in both sections of the steel pipe (see Fig. 6). Dry-mix concrete (4 parts coarse aggregate, 2 parts sand and 1 part cement) in hessian bags was then placed to give 300 mm of protection on top of and beside the ducts. The diving contractor then surveyed the trench and duct by using a video camera. Despite the murky water, an excellent picture was seen on the monitor and the Area representatives were satisfied with the duct route. The remainder of the trench was then backfilled with excavated spoil.

An unforeseen problem encountered on this section of the work was that the route chosen across the harbour coincided with the route taken by an eighteenth-century wooden footbridge. The diving contractor found a number of foundation stones (2 m×1 m×1 m) with a hole chiselled in the centre to take 300 mm square timber supports. Of the several timber supports recovered from the river bed, Weymouth Museum and Bournemouth Telephone Area each retained one for their archives.

The final stage of providing the linking ducts to existing and new jointing chambers was completed successfully without any problems. Cabling of the 4800 pr/0·32 mm cable was then started.

CONCLUSION

Despite the scale of the project, work to provide service to waiting subscribers began only 4 months after the project was started. The final cost of the whole operation was a little over 50% higher than that originally estimated. The unforeseen problems that had arisen required extra effort on the part of the various contractors and extended the time to completion; therefore, this departure from estimate is not considered unreasonable.

Evidence of the existence of a wooden footbridge as suggested by a painting on the wall of an adjacent public house would not, for instance, have necessarily led to the belief that the foundations still existed. Nevertheless, on a project of this scale, time spent on surveys and research is time well spent.

This project was the result of a team effort between Bournemouth Telephone Area, BT South-West Headquarters and BT Headquarters. All those who contributed learned much from the experience and can feel well satisfied at its successful completion.

Book Reviews

Telecommunications Transmission Handbook (second edition). Roger L. Freeman, John Wiley & Sons Ltd. xxvii+706pp. 250 ills. £36·75.

This handbook provides a broad overview of the various transmission systems to be found in telecommunications networks. It describes the essential concepts and techniques of the various systems and services. After an introductory chapter, the following topics are covered: telephone transmission, frequency-division multiplex, high-frequency radio, line-of-sight microwave radio, tropospheric scatter, earth-station technology, digital data transmission, coaxial-cable systems, pulse-code modulation systems, video transmission, facsimile, fibre optics, and digital radio.

There is an understandable emphasis on North American standards and practices, but wherever possible many references have been made to other national and international standards; in particular to the recommendations of the International Telegraph and Telephone Consultative Committee (CCITT) and the International Radio Consultative Committee (CCIR).

The treatment of the subjects in the book is essentially superficial and experts will not be at all satisfied with the way their particular subject has been dealt with. Again, all handbooks are destined to be out-of-date the day they are published, and this one is no exception. However, the key facts of each discipline are all dealt with, so the main virtue of the handbook is to lead enquirers to the appropriate authorities. It should prove useful for introducing young engineers to unfamiliar topics, and perhaps for those concerned with overseas markets.

S. MUNDY

Electronics 3 Checkbook S. A. Knight. Butterworths. vi+105pp. 119 ills. £6·95.

This is another useful little book in the Checkbook series covering the Technician Education Council's (TEC's) unit in electronics at level 3. The established pattern is followed; that is, each subject area is briefly covered, followed by a number of worked problems and then short answer problems, multi-choice answer problems and conventional problems, all with answers given where appropriate, for the student to attempt himself.

The subjects covered are small-signal amplifiers; the field-effect transistor; resistance-capacitance networks; feedback; unwanted signals: noise; stabilised power supplies; large-signal amplifiers; and oscillators. Unfortunately, there are many errors which must test the student's confidence. For example, in the chapter on feedback there is confusing inconsistency in the use of upper and lower case for V_o and A_v, and in one instance β has been missed out of the condition $\beta A_v = 1$. On page 39, of the 4 answers given to the 4 parts of question 6 of the short answer problems, only one is correct. On pages 11, 12 and 35, 10^{-3} has been printed instead of 10^3.

If a student can spot the errors, he will still find this book a useful aid to revision.

R. HARVEY

Installation of a TXE4A at Clevedon

R. MORRIS†

A new TXE4A exchange has recently been brought into service at Clevedon. The exchange, the first TXE4A exchange to be brought into service in the South-West Region, was delivered to site and installed in modular fashion by using a method known as the *Modular Installation of Telephone Equipment Racks.*

The contract for the new exchange equipment was placed with Standard Telephones and Cables plc (STC) in July 1978. At this time, STC were experimenting with the process of building exchange modules in their factory and then delivering these complete units to the exchange site. An agreement was made with STC for this method of installation to be used for the Clevedon exchange. (The method was also used for the installation of the first TXE4A exchange, which was installed at Leicester.*)

The complete exchange was built, tested and commissioned in STC's factory at New Southgate. The exchange was then broken down into 6 modules, each consisting of 2 suites (or parts of suites) of racks. The cable grid and inter-rack cabling were included in the modules, together with the overhead lighting and ring main circuits. The 2 suites in each module were clamped together ready for transportation. The largest module consisted of 2 suites of 8 racks each, weighing a total of about 12 t, and the smallest consisted of 2 suites of 3 racks each.

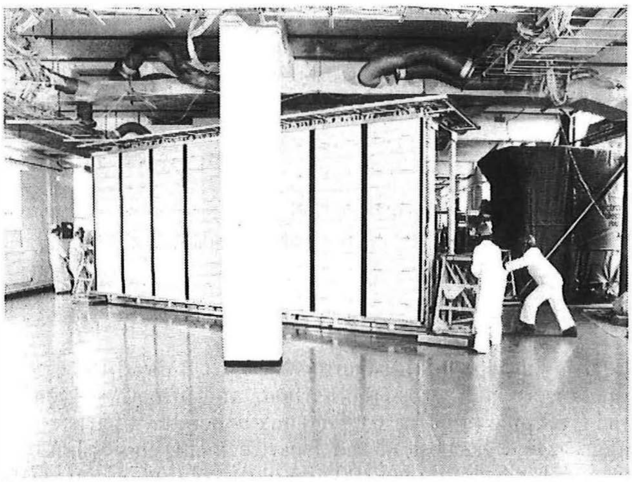


FIG. 2—A module being positioned on air bearings

FIG. 1—A module being manoeuvred into the apparatus room

In preparation for the delivery of the modules to the exchange site, STC installed the meter racks, the Strowger-type racks, the meter intermediate distribution frame and the main distribution frame. The cabling and wiring of these racks and frames were also carried out as far as possible. A builder was contracted to cut a hole approximately 4 m×3 m in the wall of the apparatus room through which the modules could be delivered. Temporary doors were fitted as a protection against the weather.

The first 3 modules were delivered to site by 3 low loaders on 23 July 1981, and the final 3 modules on 4 August. A large crane was used to lift the modules up to the first-floor level and manoeuvre them through the hole in the wall of the apparatus room. Fig. 1 shows the operation in progress; the remotely-controlled hydraulic arms that were used to keep the modules level can also be seen.

The problem of moving the heavy equipment into position once it was in the building was overcome by the use of air bearings, like small hovercraft, one of which was fitted at each corner of the modules. By using these, the modules could easily be moved within the confined space into their correct position (see Fig. 2).

By 30 March 1982, power had been connected, the cabling had been completed and the functional testing and a successful multi-call-sending programme had been carried out. STC then made some design modifications to the exchange before it was finally handed over to British Telecom on 11 June 1982. After further testing had been completed, the exchange was brought into service on 8 September 1982.

Estimates have shown that the time spent on the site by the contractor's and British Telecom's staff was reduced by about a year by using this method of installation. Since the exchange was brought into service it has been working satisfactorily and only a few minor faults have occurred.

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† Bristol Telephone Area

* RITCHIE, D. A., and LAWRENCE, L. H. The First TXE4A Exchange. *Post Off. Electr. Eng. J.*, July 1981, **74**, p. 137.

The Use of Liquid Petroleum Gas in British Telecom Motor Vehicles

N. GRAHAM†

INTRODUCTION

Liquid petroleum gas (LPG), which is the common name for all volatile hydrocarbon compositions consisting of petroleum and natural gases, has for many years been available as an alternative to petrol as a fuel for motor vehicles. Claims have often been made that by using LPG instead of petrol, fuel costs can be saved and the life of engine oil, sparking plugs and engines can be extended.

Between 1970 and 1976, British Telecom (then the British Post Office) carried out a limited field trial into the use of LPG in its vehicles, but it was concluded that only minimal savings could be achieved. By 1979, the relative costs of LPG and petrol had changed and there was an increasing use of LPG in fleet-operated vehicles. Consequently, British Telecom renewed its interest in LPG and launched a further trial, in the North-East Region; this showed that, in certain circumstances, LPG was a viable alternative to petrol.

LPG IN MOTOR VEHICLES

LPG for motor-vehicle use is composed of approximately 90% propane and 10% propylene. At one time there was a high proportion of butane in LPG; however, because of the higher rate of vaporisation of propane from the liquid state (in which it is stored), especially at low temperatures, the proportion of propane for automotive LPG has been increased, and now there is only a small quantity of butane included.

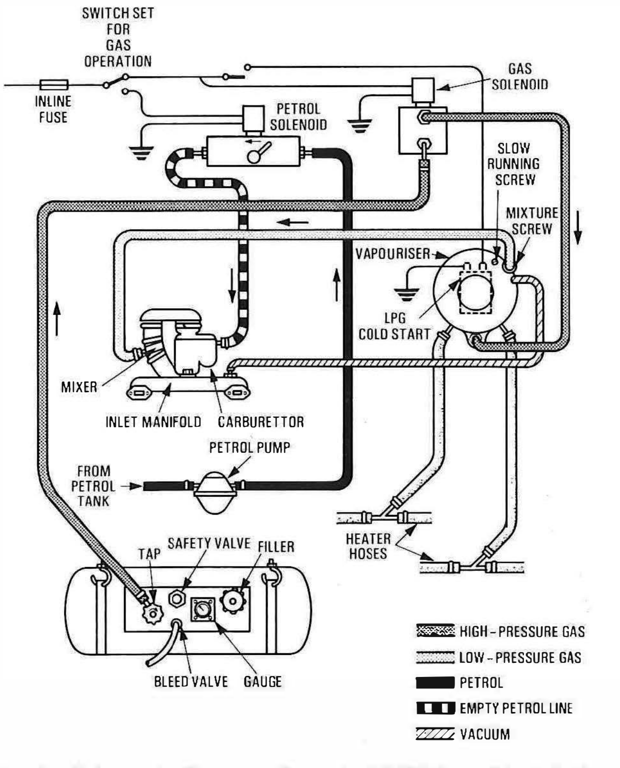

FIG. 1—Schematic diagram of a typical LPG/petrol installation

Although LPG has a higher calorific value by weight (heat content) than petrol, it has a lower specific gravity. This means that LPG has a lower calorific value by volume—1 litre of petrol is equivalent to 1·31 litres of LPG.

The main components of an LPG system for motor vehicles (see Fig. 1) are as follows:

(*a*) *Pressure Tank* Tanks with capacities in the range 36·4 litres (8 gal) to 118·2 litres (26 gal) are available.

(*b*) *Valves* Four valves are usually fitted to the pressure tank: the filler valve, the ullage valve (overflow), the safety relief valve and the liquid take-off valve.

(*c*) *Reducer (Vapouriser)* This unit receives the LPG from the tank under pressure and reduces the pressure of the LPG in 2 stages to slightly below atmospheric pressure. The LPG is retained in the reducer until it is drawn into the engine.

(*d*) *Mixer Plate* The mixer plate blends air and LPG entering the engine. There are mixer plates to suit different engines and they are fitted in different positions depending on the type of carburettor fitted.

(*e*) *Stopcocks* With dual-fuel systems (that is, where either LPG or petrol can be used), 2 stopcocks are fitted to allow the type of fuel to be selected. These stopcocks are usually solenoid valves, electrically operated from a single dashboard switch.

There are approximately 500 refuelling points for LPG in the UK and this compares with 25 000 petrol stations.

FIELD TRIAL

For the field trial in the North-East Region, 152 Commer/Dodge 15 cwt panel vans were converted to operate on LPG. Equipment from 4 manufacturers was used: Impco (50 vans), Landi Hartog (51 vans), Tartarini (50 vans) and Renzo Landi (1 van). All of these vehicles, with the exception of the 50 fitted with Impco equipment, which could only be run on LPG, could be operated with petrol or LPG. These, together with 50 petrol-driven control vehicles, were distributed to Bradford, Leeds, Middlesbrough and Sheffield Telephone Areas.

Oil samples were taken from a number of these vehicles at every full inspection to determine the condition and rate of consumption of the oil. However, this analysis did not show any significant improvement with the LPG vehicles.

Fuel consumption was analysed over a period of 9 months, and average fuel consumption figures were obtained for each manufacturers' equipment. The best fuel consumption figure, for one particular manufacturer's equipment, was 19·46 litre/100 km (14·53 miles/gal), but no statistically significant variation between fuel consumptions obtained with different manufacturers' equipment was found. The performance of the petrol-driven control vehicles was better, with an average fuel consumption of 16·19 litres/100 km (17·45 miles/gal). This difference between the fuel consumptions of the LPG vehicles and the petrol vehicles was statistically significant.

As there were not many LPG refuelling points, vehicles had to be driven some distance for refuelling. Increased fuel consumption, and the limited space available on the Commer/Dodge panel van for the LPG tank, reduced the overall range of vehicles using LPG. In addition, as some refuelling

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† Energy, Transport and Accommodation Department, British Telecom Headquarters

points were not open after 18.00 hours, some vehicles used for shift work could not be converted.

Performance tests carried out on a number of randomly-selected petrol vehicles and LPG-driven vehicles failed to reveal any significant difference between either of the types. Although some mechanical failures did occur on the LPG-driven vehicles (for example, burnt exhaust valves and sticking throttle spindles), nothing was found to indicate that there was any significant difference between the maintenance costs of the LPG- and petrol-equipped vehicles.

ECONOMIC CONSIDERATIONS

Factors such as the cost of equipment and the relative costs of petrol and LPG have a significant effect on the annual mileage above which it is more economic to use LPG. The cost of fuel is made particularly sensitive by the way in which it is taxed; at present, the tax levied on LPG is half as much as that on petrol. Until recently, the way in which the vehicle excise duty was applied also had an effect on the break even annual mileage. Under the provisions of the Vehicle Excise Act of 1971, vehicles running on LPG were given an allowance on their unladen weight for taxation purposes, and this reduced the duty payable. However, as a result of the Finance Bill of 1982, goods vehicles are now taxed by gross weight and the same duty is levied on LPG vehicles as on petrol vehicles. However, even though this cost advantage has been removed, LPG is still a viable alternative to petrol in the right circumstances.

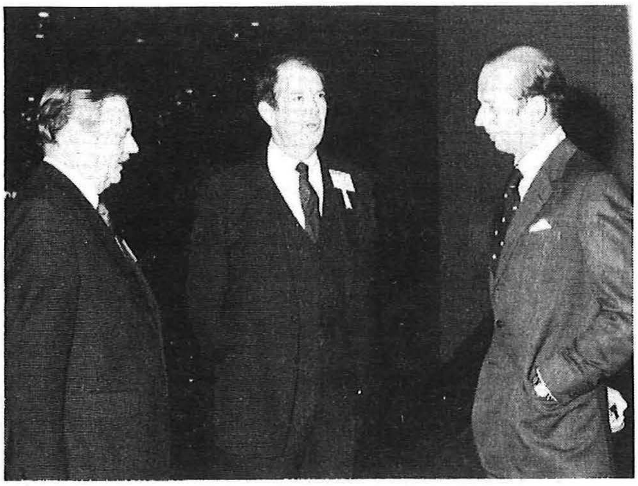
RECOMMENDATIONS

After the field trial had been concluded, the recommendation was made that Regions should decide locally whether any vehicles should be converted to run on LPG, depending on the local cost and availability of LPG, the annual mileage of vehicles and the need to have alternative fuels available. It was further recommended that dual-fuel systems be fitted, rather than gas-only systems, because they were more flexible in operation.

The Sixth International Conference on Computer Communication: A Preliminary Report

British Telecom (BT) was host to the sixth International Conference on Computer Communication (ICCC '82), which was held at the Barbican Centre for Arts and Conferences from 7–10 September 1982. The Conference Chairman was Mr. J. S. Whyte, Managing Director (Major Systems) and Engineer-in-Chief, BT.

The Conference Patron was His Royal Highness the Duke of Kent, who opened ICCC '82 with an address in which he reviewed the growth of the twin technologies of computing and communication and welcomed the emphasis which ICCC '82 placed on standards and human factors. The Keynote Address on Pathways to the Information Society was given by Mr. Kenneth Baker, Minister of State, who surveyed the evolving information technology scene in which computer communication plays a significant role.



At the Opening Session of ICCC '82—(left to right) Mr. J. S. Whyte, Conference Chairman, Professor Philip Enslow, Executive Vice-President of the International Council for Computer Communication, and HRH The Duke of Kent, Conference Patron

The opening session of ICCC '82 concluded with 3 theme speakers. Dr. I. M. Ross, President of Bell Laboratories, reviewed the progress of advancing technology in increasing the hardware content which is implemented directly in silicon, the new software architectures comprising interconnected small modules, and the increasing application of optical technologies. Mr. T. Larsson, Deputy Director General of the Swedish Telecommunications Administration, reviewed the system and business aspects of computer communications and looked towards the integration of public networks and public services. Mr. F. J. M. Laver, formerly Member of the Post Office Board for Data Processing, considered social implications in the light of the far-reaching changes which computing, communications and micro-electronics are promoting.

After the opening session, the conference was divided into 4 parallel streams of 46 sessions at which 172 papers, selected by an international reviewing panel and printed in the Proceedings, were presented. These papers included 16 from BT authors.

The Conference was very well supported, with 1630 delegates from 33 countries taking part. They represented a broad spectrum of interest which confirmed the significance of this series of conferences in bringing together telecommunications and computing technologies with users in a common forum. The sessions on public data networks, local-area networks, office systems and standards were particularly well attended.

BT, in addition to providing telecommunications services to delegates, mounted a special display of new equipment and systems that were relevant to several of the technical sessions. This included demonstrations of Teletex and examples of various X-Stream systems and services.

A fuller report on ICCC '82 is planned for a subsequent issue of the *Journal*.

M. B. WILLIAMS

The Second International Network-Planning Symposium

The UK will host the second International Network-Planning Symposium (NETWORKS '83). It is being organised by the Institution of Electrical Engineers, in association with the Institution of Electronic and Radio Engineers, and will be held at the University of Sussex, Brighton, from the 21–25 March 1983. Residential accommodation will be provided at the University.

The symposium will be opened by Sir George Jefferson, Chairman of British Telecom, and is expected to draw 400–500 delegates, many from abroad. It is the second in a series of international symposia which is recognised as the world forum for the interchange of ideas and information on the planning of telecommunications networks. The first International Network-Planning Symposium was held in Paris in 1979, and the third will be held in the USA in 1985 or 1986.

Because of an unprecedented response to the call for papers, the International Scientific Committee has been able to select 74 high-quality papers, from 18 countries, giving a balanced coverage of the latest developments and applications. These include such important topics as network optimisation and dimensioning; public, private and data networks; traffic routeing; network reliability and performance; introduction of digital systems; new telecommunications services and the integrated services digital network. These aspects are particularly topical at a time when problems are increasingly being imposed on network planners because of the significant investment being committed by Administrations for modernising networks and introducing new technology and telecommunications services.

There will be a full social programme for accompanying persons, and other social events will include a Civic Reception, welcome buffet supper and cocktail party.

More information and copies of the programme can be obtained from

Institution of Electrical Engineers,
Conference Department,
Savoy Place,
LONDON
WC2R 0BL.

K. E. WARD

Forthcoming Conferences

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

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

Fourth World Telecommunications Forum, Part 2, Technical Symposium
29 October–1 November 1983
New Exhibition and Conference Centre, Geneva

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

The Evolving Local Telecommunications Network
20–25 March 1983
Vacation school at the University of Aston

Second International Network-Planning Symposium (Networks '83)
21-25 March 1983
University of Sussex

Third International Conference on Antennas and Propagation (ICAP 83)
12-15 April 1983
University of East Anglia

Third International Conference on Satellite Systems for Mobile Communications and Navigation
7–9 June 1983
Institution of Electrical Engineers

Fifth International Conference on Software Engineering for Telecommunications Switching Systems
4–8 July 1983
Lund, Southern Sweden

Second International Conference on Radio Spectrum Conservation Techniques
6–8 September 1983
University of Birmingham

Third International Conference on Reliability of Power Supply Systems
26–28 September 1983
Institution of Electrical Engineers

Second International Conference on Advanced Infra-Red Detectors and Systems
24–26 October 1983
Institution of Electrical Engineers
Papers: Synopses by 24 March 1983

The Sixth European Conference on Electrotechnics (EUROCON)
26–28 September 1984
Brighton
The theme of the conference is to be "Computers in Communications and Control"

Institution of British Telecommunications Engineers

(formerly Institution of Post Office Electrical Engineers)

General Secretary: Mr. R. E. Farr, TE/SES 5.3, BT Research Laboratories, Martlesham Heath, Ipswich, IP5 7RE: Telephone Ipswich (0473) 644803
(Membership and other local enquiries should be directed to the appropriate Local-Centre Secretary as listed in the October 1982 issue)

AMENDMENTS TO THE RULES OF THE INSTITUTION

New Institution Rules concerning FITCE Group membership, subscriptions, income and expenditure have been accepted by the Members of that Group in accordance with Rule 34Y and became effective on 1 September 1982, having been certified by the Chairman of Council as not affecting the intended operation of the Rules, in accordance with Rule 33. The new Rules read as follows:

"The Federation of Telecommunications Engineers of the European Community (FITCE)

"63. Membership of FITCE shall be open to Corporate Members of the Institution who possess the appropriate entry qualifications as defined by FITCE. IBTE Members of FITCE shall collectively be known as the FITCE Group of IBTE for administrative purposes.

"64. The annual subscription for membership of the FITCE Group of IBTE shall be as determined by Council, advised individually to the Members of that Group in accordance with Rule 33 and published in the Journal. The subscription shall cover the required payment to FITCE plus an allowance for administrative costs incurred by the Institution such that no charge proper to FITCE Group affairs has to be met by the general membership of the Institution. Subscriptions shall be payable by 1 October each year and Rules 14 and 15 shall apply in respect of default of payment or resignation.

"65. FITCE Group income and expenditure shall be separately identified as such in the Institution Financial Statement."

ASSISTANT SECRETARY (FITCE)

The Institution has appointed Mr. P. A. P. Joseph, an Assistant Executive Engineer in the Overseas Liaison and Consultancy Department, British Telecom Headquarters, to be the Assistant Secretary (FITCE). He will henceforth be responsible for maintaining the FITCE Group membership records, for collecting subscriptions, for managing the FITCE Group account and for liaison with the FITCE Secretariat in Brussels. Any enquiries on these matters should in future be addressed to him; his address and telephone number are as follows:

Mr. P. A. P. Joseph,
BTHQ/OLC6.1.1,
Room 314,
Broad Street House,
55 Old Broad Street,
London EC2M 1RX
Tel: 01-588 8970

MEETING OF LOCAL-CENTRE SECRETARIES

The 1982 annual meeting of Local-Centre Secretaries, under the Chairmanship of the General Secretary, discussed a wide range of topics, including the implementation of the experimental scheme announced in the last issue whereby speakers at Institution meetings no longer need to produce an accompanying paper in order to be judged for the award of medals. Much time was devoted to consideration of the effects of changes in the British Telecommunications environment upon Institution activities and the question has now been referred to Council. Attention was drawn to the difficulty of maintaining contact with Postal members since separation, and proposals to alleviate the problem are being considered.

R. E. FARR
Secretary

Notes and Comments

CONTRIBUTIONS TO THE JOURNAL

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

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

GUIDANCE FOR AUTHORS

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

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

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

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

Contributions should be sent to the Managing Editor, *British Telecommunications Engineering,* IDP 3.9, Room 704, Lutyens House, Finsbury Circus, London EC2M 7LY.

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FITCE is an organisation with similar objects to IBTE and draws its members from the public telecommunications administrations of Belgium, Denmark, Eire, France, Greece, Italy, Luxembourg, the Netherlands, the UK and West Germany. FITCE publishes a quarterly Journal from its Brussels headquarters, sponsors multi-national study groups (Commissions) to enquire into and report on problems of general interest, and each year organises a General Assembly/Congress in one of the member countries at which members are invited to present papers.

Full membership of FITCE in the UK is available only through IBTE. Members and Affiliated Members of IBTE who hold a University science degree or who are Chartered Engineers may join through the FITCE Group of IBTE. The annual subscription for 1983/84 has been fixed at £5.00; this covers local administration expenses as well as the per-capita contribution to FITCE funds, and thus ensures that no charge proper to FITCE affairs will fall upon the general membership of IBTE. Membership forms are available from your Local-Centre Secretary (see p. 184 of the October 1982 issue of this *Journal*) or direct from the General Secretary.

THIS IS YOUR OPPORTUNITY TO PLAY AN ACTIVE PART IN CO-OPERATION WITH TELECOMMUNICATIONS ENGINEERS FROM OTHER EUROPEAN COUNTRIES

British Telecom Press Notices

MORE TELEPHONES TAKE CARDS INSTEAD OF CASH

Last September, British Telecom (BT) announced a multi-million pounds order for 8600 Cardphones—public telephones which take a plastic card instead of coins. The new telephones will be installed throughout the country in places such as railway stations, airports, hotels and on the streets.

The telephones first appeared as a trial during 1981 in London, Birmingham, Manchester and Glasgow. The trial was successful and BT decided to order a further 8600 telephones from Landis and Gyr of Acton, London, the company that supplied the initial 200 trial telephones.

The trial telephones were manufactured by Landis and Gyr's associate company, Sodeco, in Switzerland, but most of the new order is being assembled by Landis and Gyr in the UK and will be delivered to BT between August 1983 and Spring 1985.

As part of the order, Landis and Gyr will also be supplying 22 million of the plastic cards used to operate the telephones. The cards, known as *Phonecards*, are the same shape and size as a credit card and are imprinted by a special holographic process with 5p call units. The cards are obtainable from post offices and retail outlets near the telephones and are available in 2 values—40 units (costing £2) and 200 units (costing £10).

To make a call the user inserts the Phonecard into the telephone and "dial now" appears on the visual display. The user then keys the telephone number being called on the keypad. The visual display then shows the number of units stored on the card. As the call progresses, call units on the card are erased and the display changes to indicate how many units are left on the card. At the end of the call the card is returned to the user for future use.

Emergency calls can be made from the telephone without the card.

The trial showed that the telephones are highly reliable; during the trial they took nearly twice as much revenue as the telephones they replaced. Research has shown that one of the attractions for users is the convenience of using a card instead of having to search for coins.

Cardphone—public telephone which takes plastic cards instead of coins.

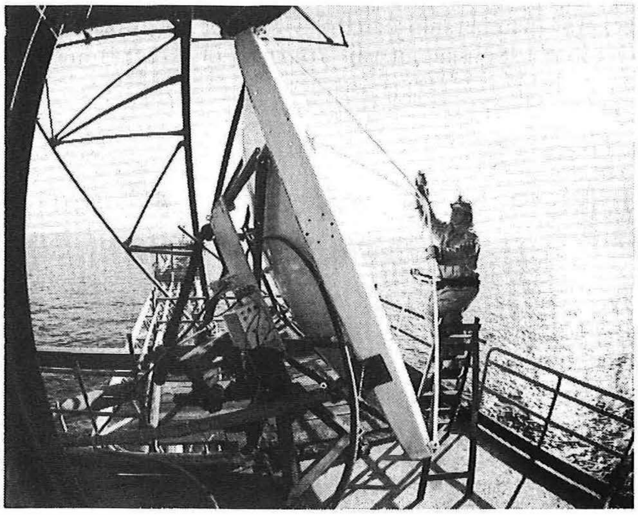
SATELLITE SERVICE FOR OFFSHORE OIL AND GAS INSTALLATIONS

Speaking at a seminar on offshore communications in October 1981, David Withers, Chief Engineer of British Telecom International (BTI), outlined the new satellite service that is to augment the present service based on transhorizon microwave radio links. A satellite service will enable BTI to set up links with areas, such as the west of Shetland, not covered by the present service.

BTI have started detailed discussions with Britain's oil and gas industries to determine their precise requirements and likely demand for satellite communications, so that BTI can draw up technical plans for a service tailored to meet exactly their needs.

The service is expected to be a special application of SatStream—a satellite-based X-Stream digital service which is to be offered to UK businesses in 1984 to provide specialist private communications within the UK and Europe. A trial of SatStream is now underway between the UK and the Amoco *Montrose Alpha* oil production platform, 193 km east of Aberdeen.

SatStream uses small dish aerials, normally from 3·7 m to 5 m in diameter, installed on or near customers' premises. Because SatStream uses digital transmission, it can offer a range of services—voice, data, text, video, and facsimile—on the same radio carrier. Such services will be of great potential benefit for communication with the offshore installations.



Adjustments being made to the dish aerial on the Amoco *Montrose Alpha* oil production platform.

British Telecom Press Notices

NEW TESTING EQUIPMENT FOR TELEPHONES

A new tester which can be used to test telephones to the Government's new standards for private attachments is now available to Industry as a result of work carried out at the British Telecom Research Laboratories.

The new tester, nicknamed *Tigger*, uses a computer to carry out a test programme automatically. By using this new system, tests which were previously too complex or too lengthy to undertake manually can be carried out easily and quickly. The equipment can be operated by non-specialist staff; instruction on how to use the system is given by British Telecom (BT) engineers when it is installed.

Tigger has already been sold to the British Approvals Board for Telecommunications (BABT)—the independent authority set up by the Government under the British Telecommunications Act 1981. The first standards for telecommunications equipment submitted to the BABT were announced on 14 October 1982.

Manufacturers can use Tigger to check that their telephones meet the standards before they submit them to the BABT for official testing. One Tigger has been sold to a private telephone supplier and more are being made to meet further demand. The equipment is also suitable for use overseas; its modular design enables the testing programme to be changed quickly and cheaply to suit the technical standards of other countries' networks. The software can also be changed so that tests can be carried out to different standards.

The test equipment, designed by BT, comprises 4 units:

(*a*) a standard 483 mm (19 in) rack, a case containing the current feeding bridges, an artificial voice equaliser/amplifier, an artificial line, conditioning control circuits and special test networks, together with a power unit;

(*b*) an acoustic cabinet complete with stand (1·5 m × 1·5 m × 1 m), which provides the quiet acoustic environment for the tests;

(*c*) an artificial head, on which the loudness rating guard-ring position can be set up, complete with handset holder and motor unit to allow carbon microphones to be conditioned (as defined by the International Telegraph and Telephone Consultative Committee (CCITT)); and

(*d*) floppy disks containing the software to run the standard tests defined in the new standard for the transmission aspect of telephone testing.

In addition, users of the new equipment will need to provide some proprietary items, notably: a Hewlett Packard 9825 computer controller, disk drives, plotter, printer, Solartron frequency response analyser, and Bruel and Kjar microphones and amplifiers.

Prospective purchasers should contact Mr. S. G. Young, Technology Executive Liaison, British Telecom Research Laboratories, Martlesham Heath, Ipswich Suffolk, IP5 7RE.

NEW OPERATOR EQUIPMENT SAVES TIME AND MONEY

British Telecom (BT) recently placed a contract with the Bracknell Division of British Aerospace Dynamics Group for the supply of new automatic call recording equipment (ACRE). The ACRE will save up to 20% of a telephone operator's time when connecting calls and will enable operators to devote more time to helping customers. The new equipment will bring savings of more than £3M a year.

The ACRE harnesses the power of microprocessors to abolish the time-consuming task of writing details of operator-handled calls on a paper "ticket". This ticket—which notes the caller's number, number dialled, time of day, charge rate and call duration—is at present used for calculating the charges for operator-controlled calls which appear on a customer's phone bill.

With the ACRE, details are automatically recorded on magnetic tape as the call is set up and are subsequently processed in BT's computer-based telephone billing system. The ACRE stores only the details for billing purposes; it cannot record the call itself.

After the successful trial of the ACRE at Eastbourne, BT is now going to install the equipment on over 2000 of its operator positions in switchboards throughout the country—about half of the total number.

The switch rooms to be fitted with the ACRE have modern cordless switchboards, at which operators already connect calls by pressing keys. BT is also trying out the equipment on one of its older-type switchboards fitted with cords and plugs. It has already been proved that the ACRE gives comparable savings in these surroundings.

Because Britain's telephone network is fully automatic, customers call the operator only when they need help with calls or when they want information or a special facility; for example, credit-card or transferred-charge calls. But with the continued growth of the telephone system, the number of calls connected by operators is still significant. In 1981–82 there were 91 million operator-controlled calls—on average, a quarter of a million a day. The ACRE will enable operators to deal with these calls more efficiently.

Whenever a customer dials 100 to ask for help with a call, the operator who answers has to:

(*a*) record the call charging details on a printed paper ticket,

(*b*) set up the call by pressing the buttons of a keypad, and

(*c*) start timing the call once the called person answers.

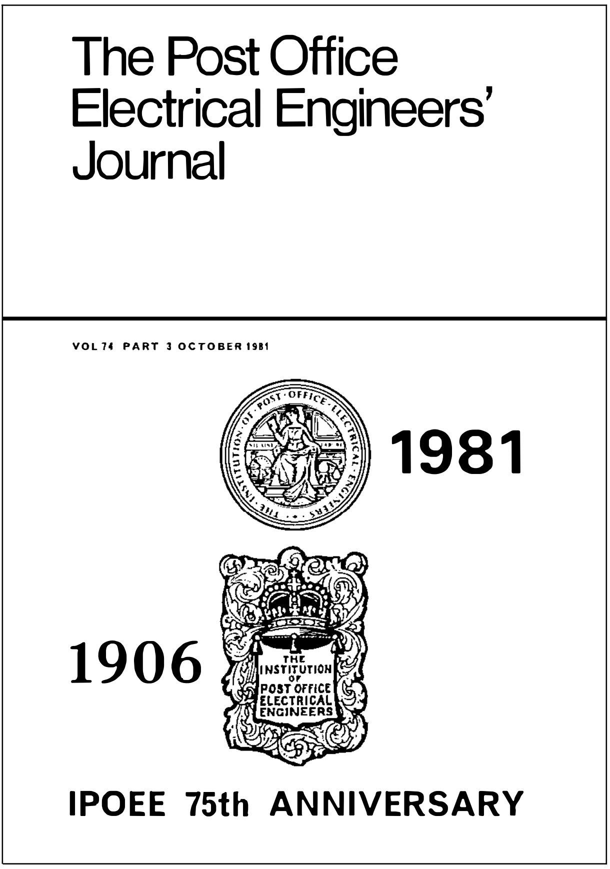
On average, this takes an experienced operator about 80 s. The operator also has to monitor the CALL INDICATOR lamps, which glow when a call has ended, so that the duration of the call can be recorded. For special-facility calls more information has to be put on the ticket. On some calls the operator may have to call back afterwards with advice of duration and charge (ADC).

The ACRE eliminates the ticket by recording the call details automatically and reduces the time taken to handle an average call by almost 15 s. The operator at a switchboard with ACRE just keys the number on the keypad. The equipment's processor logs the call for billing purposes at the same time as setting it up. While the call is going through, the operator is busy keying in the other details.

The ACRE has its own clock, together with a complete store of all charging information. It automatically records the various factors—time of day, distance of call, and length of call—involved in calculating call charges. It even reminds the operator to call back if ADC was requested.

Call-charge details at ACRE switchrooms are recorded on magnetic tape cartridges. Each cartridge can record details of up to 40 000 calls and can be re-used about 100 times. Cartridges are sent weekly by post to BT's telephone billing computer centres at a fraction of the cost of sending trays of tickets. The information stored on the tape is transferred electronically to the computer quickly and easily.

OCTOBER 1981 SPECIAL ISSUE



The Post Office
Electrical Engineers'
Journal

VOL 74 PART 3 OCTOBER 1981

1981

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THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

IPOEE 75th ANNIVERSARY

The October 1981 issue of the *Journal* was a special double-size issue of the Journal to mark the 75th Anniversary of the Institution of Post Office Electrical Engineers. The issue contains articles which review the changes that have taken place in telecommunications and postal services over the past 25 years. In particular, the following broad topic areas are covered: the inland network; international services; switching and signalling; mechanical and civil engineering; customer apparatus; transmission and postal engineering.

In one article, these changes are related not only to the technological advances that have taken place during the period, but also to the changes in the social and economic environment. In a further article, Mr. J. S. Whyte, the President of the Institution, discusses those areas in which rapid advances in technology will have the most profound influence on telecommunications. He shows how these changes have already started to shape, and speculates how they will continue to shape, the future of telecommunications over the next 25 years.

The important contribution made by the British Telecommunications Research Laboratories (BTRL) to these developments are described in an article which highlights some of the major activities, including many which have led the world, that have been carried out at BTRL over the past 25 years.

The issue also includes an article describing the history of the Institution since its formation in 1906.

Copies of this issue may be ordered by completing the order form below and by sending it to the address shown. The cost of the issue is £1.30, including post and packaging (the cost to British Telecom and British Post Office staff is 48p). (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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British Telecommunications Engineering

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The 26 articles on System X which appeared in the *Journal* between January 1979 and April 1981 have been reprinted as a single 160-page book. The articles in this book describe:

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(*b*) The principles of the system, including aspects related to digital switching, common-channel signalling, and processor control.

(*c*) The individual subsystems.

(*d*) The hardware and software.

(*e*) The design and support of modern switching systems.

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

The cost of this book is £3.00 including post and packaging (the cost to British Telecom (BT) and British Post Office (BPO) staff is £1.50).

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This catalogue, which is the first completely new edition for 8 years, has been printed in A4 size and lists each book twice, under its title and under its author, with much cross-referencing. This should make the selection of books easier than was possible previously with the rigid subject index then used, particularly for books having complex titles or more than one author. A separate section lists 66 books of particular historical interest.

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British Telecommunications Engineering

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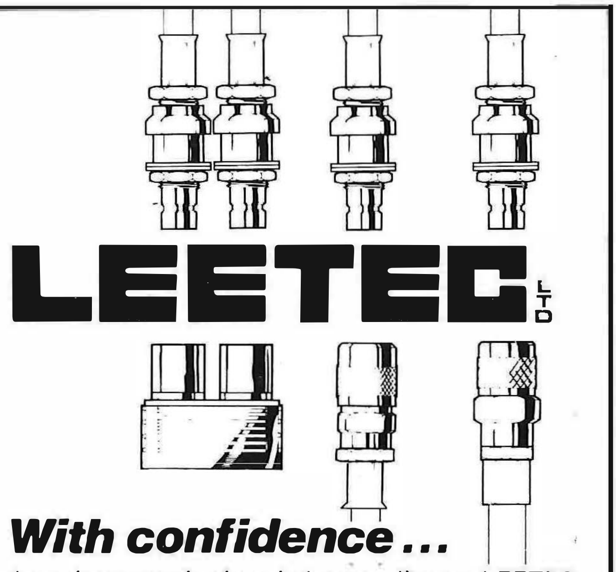

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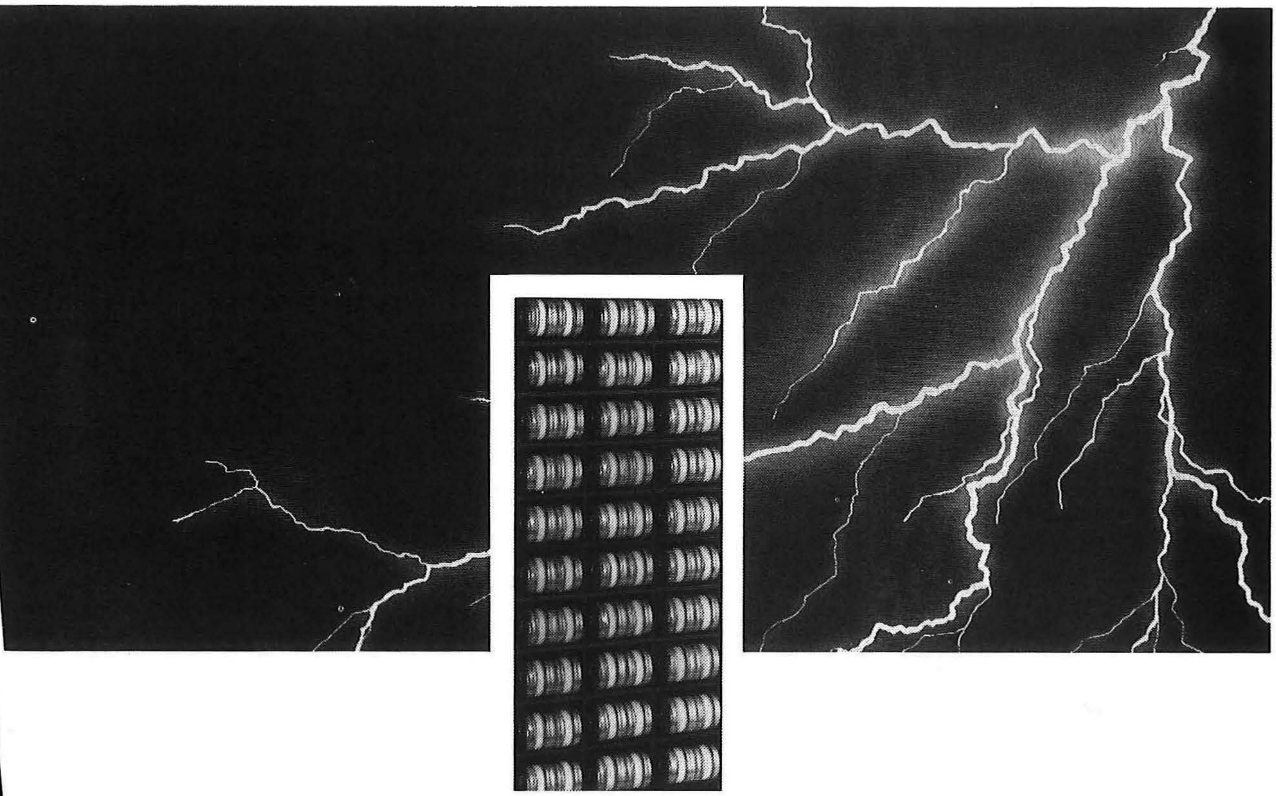

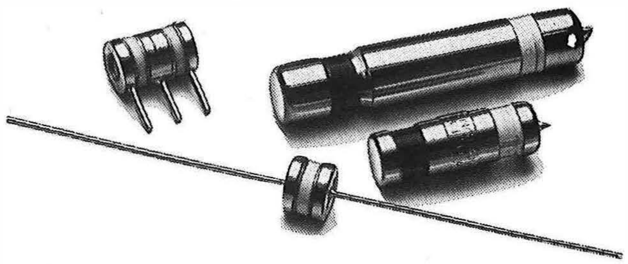

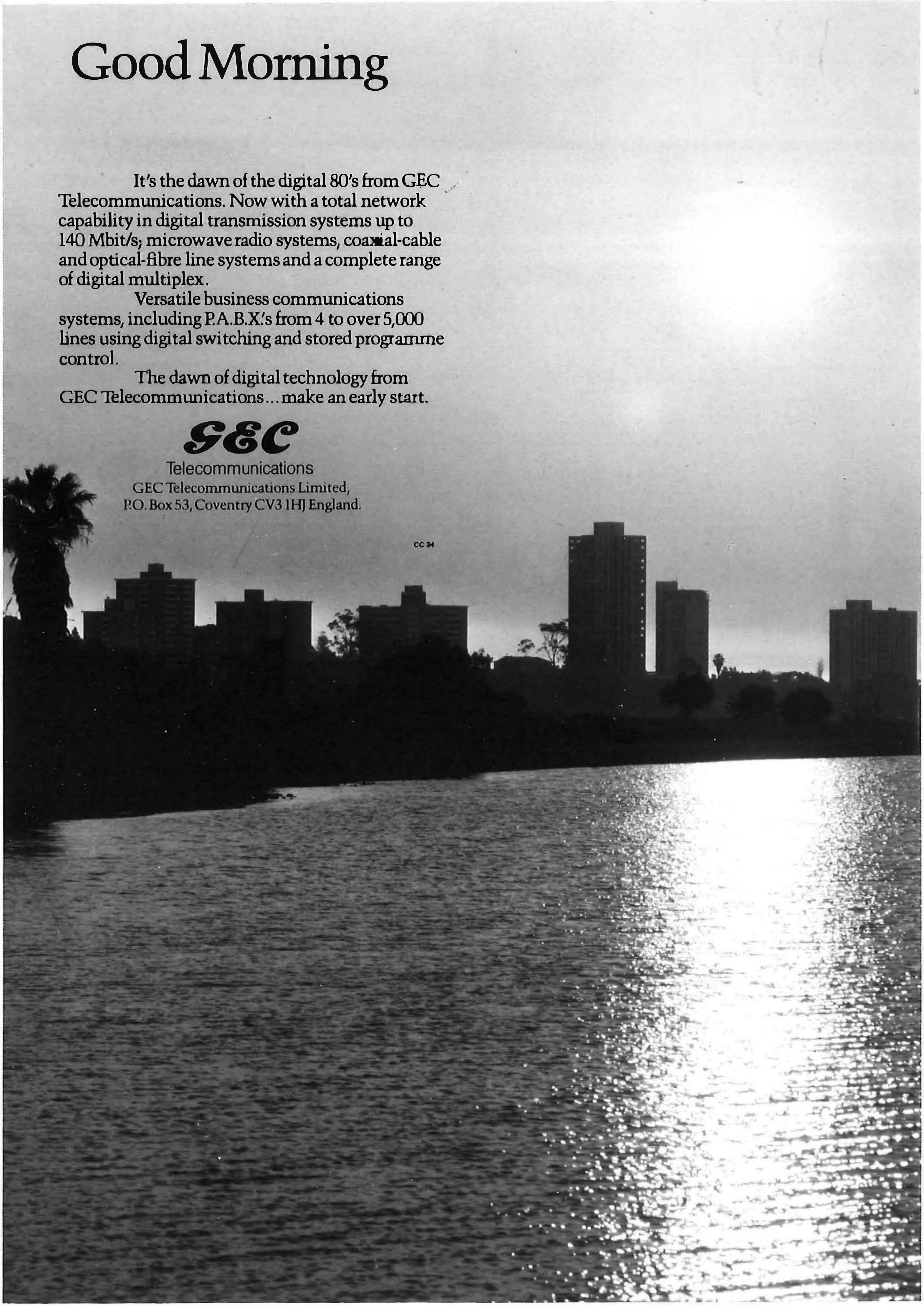

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